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Published for the Advancement of the Science and Art of Welding

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The Journal of
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The Welding of High-Temperature, High-Pressure Steel Valves*

By Vincent T. Malcolm and Sidney Low†

PROGRESS in central station design and operation has been so rapid as to sometimes bewilder men who have given their whole time and thought to this work. Present economic conditions are imposing upon us the necessity for efficiency in every phase of industrial activity, one of the most important phases being the economical generation of steam.

The fact that steam station economy may be improved by the employment of greater pressures and higher temperatures is established; but the realization of this economy is in no small way dependent upon the effective utilization of materials of construction.

Many plants will be designed for and operated at 1200 to 1400 psi. pressure and 900 to 950° F. total steam temperature, in addition to a considerable number already operating under these conditions. We have now even entered the realm of the 2000 psi., 1000° F. station. One station, approximating these conditions, is now in service and others are under consideration. There is little doubt that continued progress will be made if research and engineering continue to cooperate as in the past.

In the construction of power-plant equipment, the old adage, "A chain is no stronger than its weakest link," has a particular bearing. While valves are only a minor part of the major equipment, they nevertheless play an important part in the operation of a station. When it is considered that the outage of a unit costing many thousands of dollars may result from improper functioning of a valve costing some hundred of dollars, the design and construction of valves become most important.

With present exacting service demands and the trend toward minimum reserve capacity, reliability in valves becomes paramount. By continued research, we must emphasize the importance of design, materials, and workmanship; and organizations that have the will to pioneer and the resources to carry out such pioneer work must certainly be looked upon as progressive in the art of valve construction.

The engineer engaged in central station work needs, in valves, a comparatively cheap alloy steel that has high physical properties not greatly impaired by continued service at high temperature. The seating materials must resist seizing and galling due to the heavy sliding pressures. They must be corrosion, oxidation and erosion resistant. The metal, in all parts of a valve, must be capable of resisting, for the economic life of the equipment of which it is a part, the conditions to which it is subjected in service.

First and foremost among the difficulties in valve operation is the maintaining of tight line joints. An elaborate study of various forms of joints showed that no form of flange joint would stand up for any length of time under high temperature, without servicing. Substantiating the general opinion that a welded end joint was the practical answer, end flanges on valves were eliminated and welding ends substituted for high-temperature service.

Alloy steels were developed that would give excellent creep strength under high-temperature service conditions and, at the same time, be successfully welded.

Cast by-pass connections were eliminated and all-welded construction used.

The Chapman Valve Manufacturing Co. carried out a series of tests, some years ago, on the efficiency of bolted bonnet joints. It was found that joints would relieve themselves under a fixed or limited strain; and with the then prevalent standards of bolting set up, showed a tendency to leak after being placed in service, if the bolts were not retightened at regular intervals. After much study, it was found that there were two distinct ways of overcoming this difficulty, both of which have been adopted in our present work.

The first was to continue the use of flanged joints, with an entirely new method of bolt set up, and the second was to design and construct a welded bonnet valve. Numerous difficulties were encountered in the latter. We had to be sure that the interior working parts of the valve would resist the service for the life of the valve. However, with hard facing materials on the seat rings and disks, the welding of seat rings in place, the hard facing of packing collars and the welding of by-pass and drip connections, it has been possible to design and construct welded bonnet valves and obtain the required service life in central stations.

All of this welding presents an entirely new picture when it is remembered that not long ago fusion welding was looked upon as unsatisfactory. Due to constant improvements in materials, apparatus and welding techniques, welding is now universally accepted as a tool of modern industry, with all of its possibilities still unexplored.

Great care must be exercised in all welding for high-temperature pressure work. The disastrous results which might ensue from failure of a welded joint dictate that every precaution be taken in guarding against interruption of service. The complete snapping off of a joint in a large high-pressure line would indeed be a major disaster and the results not pleasant to contemplate. Such a possibility is not wholly outside of the

* Presented at the Annual Meeting, A.W.S., Atlantic City, N. J., week of Nov. 17, 1946.
† Director of Research and Research Engineer, respectively, The Chapman Valve Manufacturing Co., Indian Orchard, Mass.

picture, since conditions of severe shock sometimes occur both on boiler feed lines and turbine leads due to the sticking of a feed regulator or the sudden tripping of a turbine. Whipping of the lines under these conditions has been known to assume alarming proportions and any strength welds in the lines should be capable of sustaining heavy impact. The development in a joint of even a small crack, sufficient to constitute a leak, would be at best a disquieting event which might cause inopportune shutdown for repairs.

Hence, the necessity for insuring (1) that none but thoroughly competent operators practice welding for this type of work; (2) that their work be adequately supervised and inspected; and (3) that when feasible, particularly on new designs, pilot welds be cut up and examined for flaws, lack of penetration, etc.

Research and scientific study have done much in recent years to advance welding processes, for it was only a few years ago that the A.S.M.E. codes and insurance companies would not allow welded joints on pressure vessels. Therefore, this new advance has involved investigations of both welding processes and characteristics of metals to be joined. In the early days of the welding art, basic qualities of material were often thought to be at fault, whereas recent work has shown that either the welding process, equipment or filler rods could all adversely affect the result.

The development of the covered electrode, more than anything else, has made it possible to produce sound, clean, strong, ductile welds, with practically no limitations in thickness, by the use of multilayer deposits and the shielding of the arc by the atmosphere obtained from the electrode coating.

In our opinion, satisfactory welds in low-alloy steel are dependent upon the following:

1. Skill of the operator.
2. Design of welding bevels or joints.
3. Equipment.
4. Preheat arrangement.
5. Quality of base metals.
6. Quality of electrodes.
7. Welding sequence.
8. Postheat.
9. Human element.

Skill of Operators

The first problem is to train and qualify operators in the use of low-alloy electrodes.

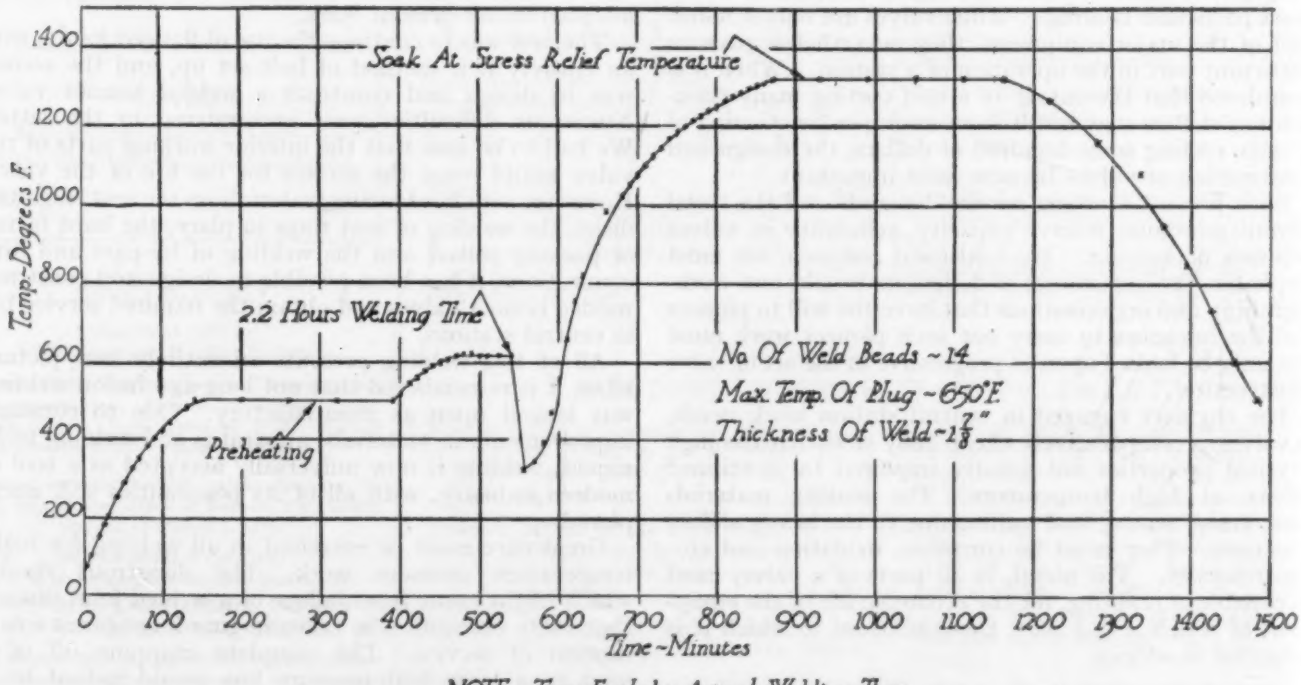
Fortunately, this has not been too great a problem since competent personnel was available. They quickly adapted themselves to the required change in technique. Individual welders can do good or bad work, and the percentage of rejects will depend on the training of operators, not under the old procedures, but under the new ones recently adopted.

Welders, in our work, must qualify under both the A.S.M.E. and United States Navy codes. They are also expected to qualify under radiographic inspection in accordance with the A.S.M.E. pressure-vessel code and U. S. Navy requirements. These rigid tests are necessary and no cutting of corners is allowed. Safety of both life and plant depends on the ability of welding operators to consistently produce good work. These tests are repeated every six months and are intended to provide adequate demonstration of the soundness, strength and ductility of each material welded. Soundness of deposited weld metal is the main criterion of an operator's ability.

The A.S.M.E. and Navy have published qualification codes, so they will not be described here.

Design of Welding Bevels or Joints

The preparation of valve ends for welding has an important bearing on the quality of the joint, and also on its cost. While it is possible to make satisfactory welds with rather widely different types of welding bevels, as evidenced by the multiplicity of designs developed by users of valves and fittings, the complication of stocking valves and fittings with different types of bevels is undesirable.



NOTE: Time Excludes Actual Welding Time

Fig. 1—Thermal History of Welded B. & B. Joint, 8-In. L 900 Weld End Outside Screw, Special Valve

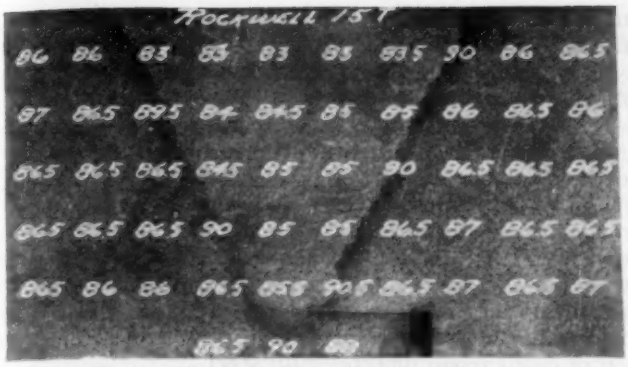


Fig. 2—Hardness Traverse Through a Butt Weld in a 4-In. Section of Cast Carbon Molybdenum Steel

A subgroup of the A.S.A. committee B16 studied existing bevels and finally recommended bevels suitable for standardization. One type of bevel recommended is for thicknesses of $^3/_{16}$ to $^3/_4$ in., inclusive, and is the $37^1/_2° \pm 2^1/_2°$ straight bevel standardized some years ago by the A.P.I. For thicknesses over $^3/_4$ in., the committee recommended, for arc welding a U bevel calling for $20° \pm 2^1/_2°$ with a $^3/_{16}$ in. radius at the bottom of the bevel. While this required a narrower groove than the recently used, 26° U bevel, with $^5/_{16}$ in. radius, trial qualification tests showed it to be entirely satisfactory.

In line joint welding, with the bevels described, it is customary to use a backing ring. The purpose of this backing ring is to permit separating the pipe ends sufficiently to enable the welding operator to penetrate to the inside wall without getting weld spatter and icicles inside the valve. Backing rings also are of assistance in aligning the ends of the valve. They may be provided with ridges, pins or tapered surfaces to give the desired separation of the ends.

Ideas as to what constitutes suitable backing rings have recently been a point of discussion. In one case, ends have been upset and counterbored to exacting dimensions so as to receive a continuous ring, completely recessed in the pipe wall. While this construction appeared very good, the expense could not be justified. On the other hand, relatively heavy sectional split rings, 2 in. wide and from $^1/_8$ to $^1/_4$ in. thick, were simply sprung into position and fitted as closely as possible to the inside diameters of the abutting ends.

Lately, the trend has been toward the use of lighter rings $^1/_8$ in. thick and about $^3/_4$ in. wide, which are partially recessed in the pipe wall. These rings are slightly tapered. Qualification tests showed that the tapered ring continued hugging the base closely instead of springing away due to contraction of the weld metal in cooling, as was the case with flat rings. The ring adopted was a continuous ring (as distinguished from a ring split like a piston ring) made with a 10° taper.

A complete design for backing rings is available and therefore tolerance, etc., will not be described.

In welding the bonnet to the body of a valve the procedure used is quite different, for here backing rings cannot be used to advantage. The male connection is on the bonnet which fits directly into the female connection on the body. This type of connection is used to obtain perfect alignment as the valves are completely assembled, with rings, disks and stem in place before welding. Any distortion taking place from the welding operation will throw the valve out of alignment and consequently it will be of no use.

The type of bevel used corresponds to the standard as previously described.

By-pass and drip connections are attached to the valve by welding. This method affords a simple and generally satisfactory attachment, and hundreds of this type now in service give ample proof of the fact that light-walled pipe can be welded successfully to much heavier sections. While it is considered desirable to have the thickness of parts joined by welding approximately equal, it is apparent that this requirement is not so essential as first thought.

Welding Equipment

Very little need be said about welding machines except that it is obvious, for d.-c. arc welding, large generators are far more efficient than small ones. It is characteristic of a welding generator set that the efficiency curve is generally flat. The efficiency of a direct-current unit may vary from 47% at 110 amp. and 25 v. to 59% at 370 amp. and 38 v. on a 400-amp. unit. Consequently, this wide range and high efficiency of large generators means lower power cost.

After a great deal of experimental work in connection with welding valves, we adopted an alternating current transformer set of 500 amp. capacity at 30 volts. It was evident that a much better weld could be produced by this equipment because of the absence of the magnetic arc blow. Another important advantage is its high electrical efficiency averaging 85 to 90% over direct-current generators. This difference in efficiency represents a saving of 30% in power consumption.

When manufacture of the welded body and bonnet-type valve was first started, all welding was performed manually. Present-day practice includes the use of automatic welding heads, both of the electronic and direct-current motor control types. The use of the automatic head has virtually eliminated all difficulties with non-metallic inclusions in the weld metal.

Preheat

The factors having tendency to produce air hardening or brittleness in a weld are, first, the presence of a sufficient amount of carbon or alloying elements to impart hardenability to the steel; and second, too rapid rate of solidification and cooling. The measures taken to combat excessive hardening in welding of low-alloy steels are: (*a*) for a given alloy composition keep the carbon content as low as compatible with adequate strength, preferably below 0.25% and in all cases never over 0.30%; (*b*) preheat the parts being joined, in and adjacent to the fusion

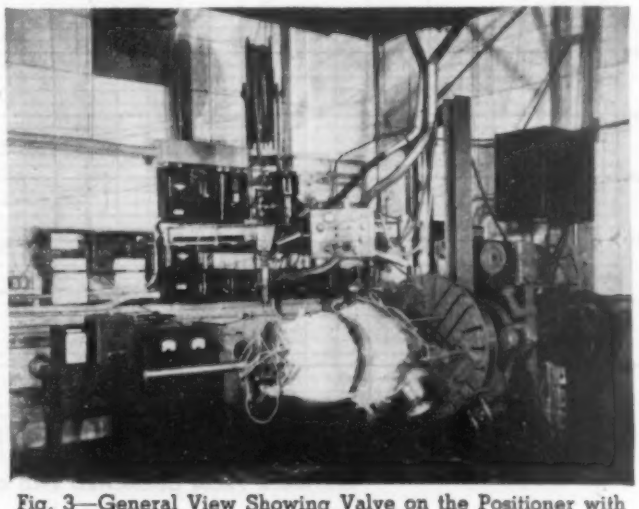


Fig. 3—General View Showing Valve on the Positioner with Preheat Coils in Place

zone, in order to delay cooling through critical regions, thus obtaining decreased hardness with greater ductility. It is generally conceded that preheat is necessary where carbon is over 0.15% in low-alloy steels or over 0.30% in carbon steels.

Preheating the entire joint about several inches on each side to 500° F. is absolutely necessary when welding alloy steels. Thermocouples should be placed so that the temperature may be checked and maintained at all times during the welding operation; otherwise, cracking may occur. While the cracks may be too small to be detected by visual examination, they may appear on the radiograph or be detected by magnetic means, thereby causing rejection of the weld. Preheating temperature should be attained in the valve at least 2 hr. before welding is started. Figure 1 illustrates the thermal history of the welding of a valve body and bonnet joint.

In steel, welded by the arc process, there occurs in the base material a definite heat-affected area extending from the bottom of the deposit to that portion of the base metal heated to the temperature of the lower transformation point of the steel. This is the apparent heat-affected zone and is visible in all welded steel. The true heat-affected zone extends beyond the apparent zone to that point in the base metal where temperature does not affect the properties of the metal. If the base metal is cold at the time of welding, or if the composition of the steel is wrong, the apparent heat-affected zone is composed of the structural element martensite, which is the very brittle constituent of steel. The metal in this area has been heated to above the critical range by the temperature of the arc and cooled rapidly by conduction. Cracks, therefore, form in the apparent heat-affected zone due to inability of this brittle constituent to resist the unequal cooling strains in the deposit and in the base. Therefore, if the base metal is properly heated prior to welding, the cooling rate in the affected zone is decreased, preventing, or retarding, brittle constituent formation. If martensite is not formed, cracks do not usually occur. In welds consisting of two beads, the apparent heat-affected zone, due to the last bead, does not usually extend to the bottom of the first bead. The true heat-affected zone extends beyond the initial bead into the base metal and usually the temperature is sufficient to temper the brittle constituent resulting from the first bead. Multiple layers do not prevent most welding cracks as these cracks are caused by the first bead, and the cracks are usually formed before the second bead can be deposited. The extent of the heat-affected zone is easily determined in the macrostructure or can be obtained by measuring the hardness of each bead. Figure 2 illustrates a hardness traverse through a weld in a 4-in. section of cast carbon molybdenum steel.

For preheating we use the following regulations:

(*a*) The parts to be joined by welding are preheated uniformly to a temperature of not less that 500° F. with an electric resistance heater or a gas-fired ring furnace, automatically controlled. The joint is at preheat temperature for at least 2 hr. before starting a major weld. Figure 3 shows a large valve on a positioner with electrical preheat coils in place. The automatic control equipment may be noted behind the valve.

(*b*) A metal temperature of about 600° F. is maintained while weld metal is being deposited or successive layers cleaned or chipped.

(*c*) Small repair welds are usually preheated with a blow torch.

Base Metal

Figure 4 shows the Jominy hardenability of various types of steel used for valve body and bonnet construction. It may be noted that the test bars were quenched from 2100° F. to simulate the temperature in the base metal adjacent to the weld deposit. A quench temperature of 2100° F. also insures complete carbide solubility. There has been a tendency, from some quarters, to use the re-

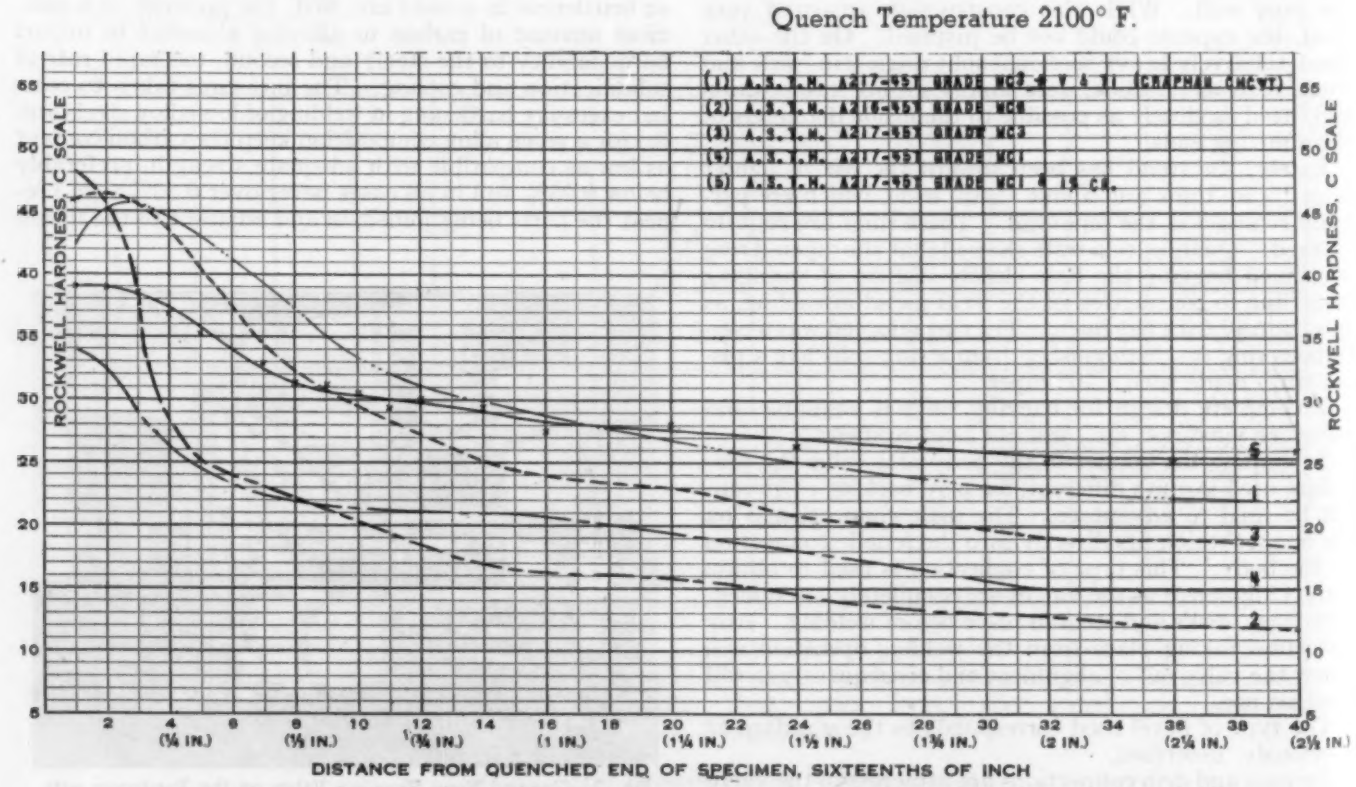
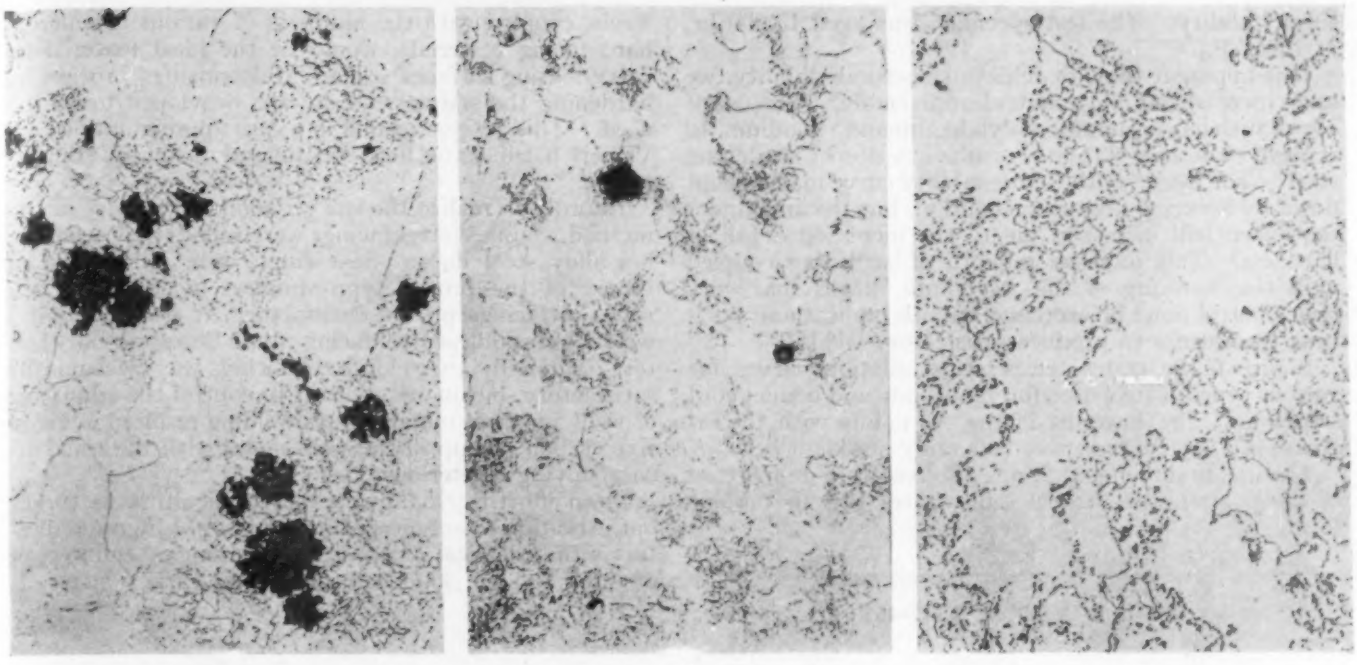

Quench Temperature 2100° F.
(1) A.S.T.M. A217-45T GRADE WC9 & V & Ti (CHAPMAN CMC VI)
(2) A.S.T.M. A217-45T GRADE WC6
(3) A.S.T.M. A217-45T GRADE WC5
(4) A.S.T.M. A217-45T GRADE WC1
(5) A.S.T.M. A217-45T GRADE WC1 & 1½ Cr.
ROCKWELL HARDNESS, C SCALE
DISTANCE FROM QUENCHED END OF SPECIMEN, SIXTEENTHS OF INCH
(¼ IN.)
(½ IN.)
(¾ IN.)
(1 IN.)
(1¼ IN.)
(1½ IN.)
(1¾ IN.)
(2 IN.)
(2¼ IN.)
(2½ IN.)

Fig. 4—A.S.T.M. Tentative Method of End-Quench Test for Hardenability of Steel (A 255-42T)



(a) (b) (c)

Fig. 5—Low-Temperature Heat-Affected Zones. Etch: Nital-Picral. × 500

(*a*) A.S.T.M. A 217-45T grade WC1, aged 10,000 hr. at 1025° F. (*b*) A.S.T.M. A 217-45T grade WC3, aged 10,000 hr. at 1025° F. (*c*) A.S.T.M. A 217-45T grade WC3 + V and Ti (Chapman CMCVT), aged 15,000 hr. at 1025° F.

sults of the hardenability tests as a measure of weldability. It has even been proposed that the ratio of carbon content to alloy content be so adjusted that an increase in alloy content will not affect the hardenability of the steel. It has been our experience that hardenability and weldability are two entirely different properties. If the thermal history of the metal is correct and sound metallurgical control is exercised, a 1% chromium, 0.5% molybdenum steel is as weldable as a 0.25% carbon steel.

As everyone in the power industry well knows, the past few years have made us all tremendously conscious of the structural instability of steels operated at temperatures above 850° F. due to graphitization. Observation of samples removed from service, as well as laboratory investigations, has proved that graphitization proceeds at a very high rate in the weld heat-affected zone in the area of the Ac_1 isothermals. Graphitization is particularly serious in this location since it results in planes of weakness that show marked decreases in both ductility and impact resistance. Since graphite is the stable end of the iron carbon diagram, it is obvious that alloying is required to retard graphitization.

Figure 5 (*a*) illustrates graphitization in the low-temperature heat-affected zone of a cast steel conforming to A.S.T.M. A 217–45T Grade WC1. The test specimen was aged 10,000 hr. at 1025° F.

Figure 5 (*b*) illustrates graphitization in the low temperature heat-affected zone of a cast steel conforming to A.S.T.M. A 217–45T Grade WC3. The test specimen was aged 10,000 hr. at 1025° F.

Figure 5 (*c*) illustrates the low-temperature heat-affected zone of a cast steel developed by The Chapman Valve Manufacturing Co. The analysis of this steel conforms to A.S.T.M. A 217–45T Grade WC3 with the addition of vanadium and titanium. This steel has been given the name of "Chapman CMCVT" steel. A special killing practice, using aluminum shot, has been developed to permit this steel to be cast into green sand molds and yet avoid the deleterious effects of aluminum on struc-

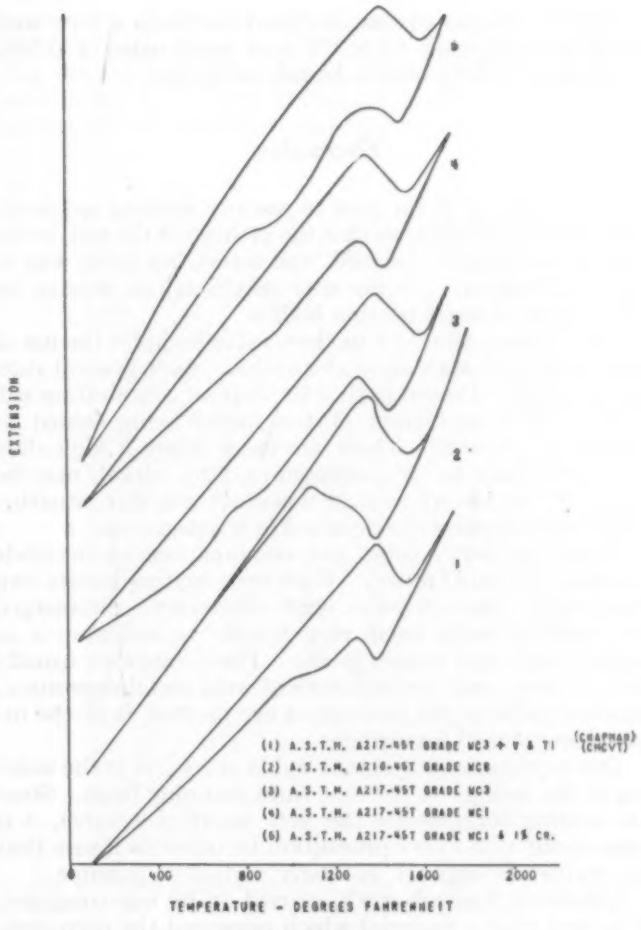


Fig. 6—Dilation Curves

tural stability. The test specimen was aged 15,000 hr. at 1025° F.

It is apparent that, to achieve structural stability, we must increase our alloy content appreciably. The use of alloys such as chromium, molybdenum and vanadium, to achieve structural stability, results in a deeper hardening steel. The height of the hardenability curve may be kept down by lowering the carbon content, but the area under the curve still increases due to the increased depth of hardness. This increase in depth of hardening coupled with the lowering of the A_R points means that very close control must be exercised in both preheat and post-heat treatments to produce satisfactory welds.

Figure 6 illustrates temperature dilation curves for various types of steel used for valve body and bonnet construction. The lowering of the A_R points with the increase in alloy content may be readily noted.

The use of alloying additions also results in an increase in creep strength. Table 1 illustrates this in tabular form.

Table 1—A.S.T.M. A 217-45T

	Grade WC1	Grade WC3	Grade WC3 + V and Ti (Chapman CMCVT Steel)
Minimum physical properties			
Tensile strength, psi.	70,000	70,000	70,000
Yield point, psi.	45,000	45,000	45,000
Elongation in 2 in., %	22	22	22
Reduction of area, %	35	35	35
Creep strength at 900° F. in psi.			
1% in 10,000 hr.	27,000	30,000	33,000
1% in 100,000 hr.	16,000	18,000	20,000

Figure 7 shows various test bars cut from a butt weld made in Chapman CMCVT cast steel using a 0.50% chromium, 0.50% molybdenum electrode.

Electrodes

The tendency in the past to use any welding rod available, on the assumption that the melting of the rod, in the course of welding, "purified" the metal, has given way to new and definite welding wire specifications written by the various standardization bodies.

The construction of a modern valve includes the use of both low- and high-alloy electrodes. As a general rule, an electrode is chosen so that the deposit composition will match the composition of the metal being joined as closely as possible. There are cases where a high-alloy electrode, such as 25% chromium, 20% nickel, may be used to join low-alloy steel when a particular situation arises that requires close control of warpage, etc.

There are many types and combinations of electrode coatings available today. Each type coating has its own distinctive characteristics and advocates. Submerged arc welding lends itself very readily to welds such as welded body and bonnet joints. These joints are usually 2–5 in. deep, and the high rate of weld metal deposition, characteristic of the submerged arc process, is of the utmost economical importance.

One of the most important welds in a valve is the welding of the facings on the seat rings and plug faces. Since the seating surfaces are the very heart of a valve, it is paramount that every precaution be taken to insure that the welded facings are as nearly perfect as possible.

Extensive research work, carried on by our company, indicated that a material which possessed the corrosion-resistant properties of the austenitic and ferritic stainless steels, coupled with the hardness of various commercial hard facing materials, would be the ideal material for valve seating surfaces. The "Malcomizing" process, for hardening the stainless steels, was developed to fill this need. This process results in a case approximating 1000 Vickers hardness on both ferritic and austenitic stainless steels.

In order to realize the full economic advantage of this method, stainless steel facings were rolled into carbon- or low-alloy steel disks. Seat rings were either cast or forged of the proper type stainless steel. While the rolled-in facings proved satisfactory, it was felt that a welded-on stainless steel facing would be appreciably better. Manually arc welding the facings was mechanically satisfactory, but it was difficult to control the admixture of weld and base metals. Gas welding resulted in excessive carbon pickup in the weld metal with the usual accompanying deleterious effects.

In an effort to circumvent these difficulties, we turned our attention to submerged arc welding. Figure 8 illustrates the chemical composition of a single bead deposit of A.I.S.I. Type 309 electrode on cast-carbon steel. It

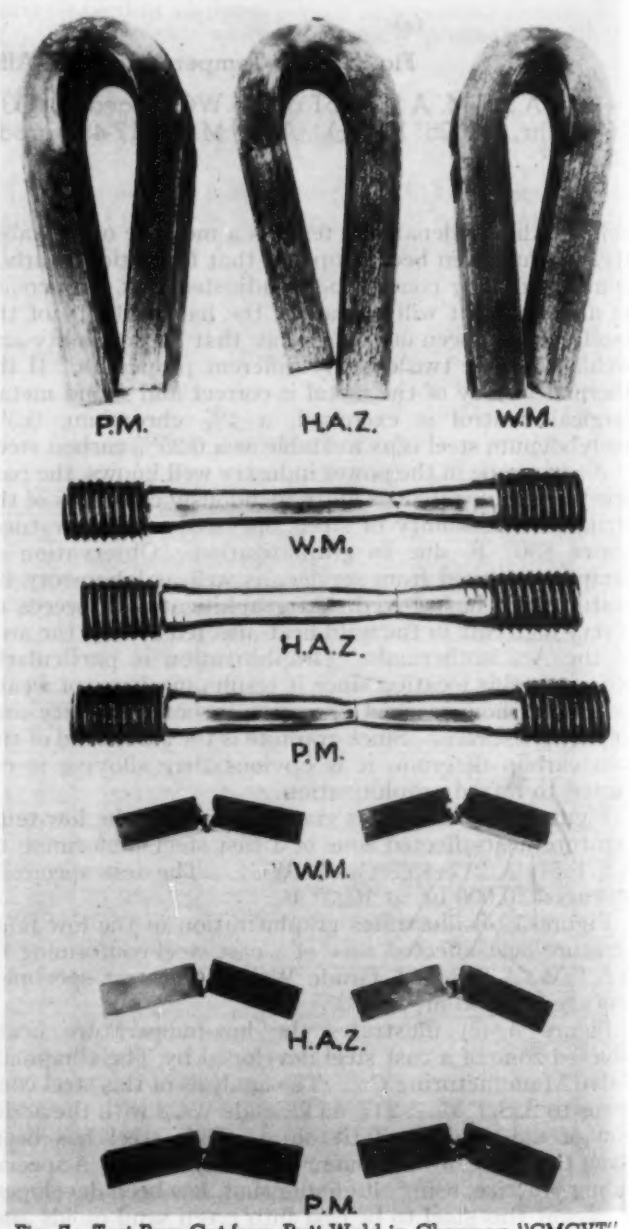


Fig. 7—Test Bars Cut from Butt Weld in Chapman "CMCVT" Cast Steel

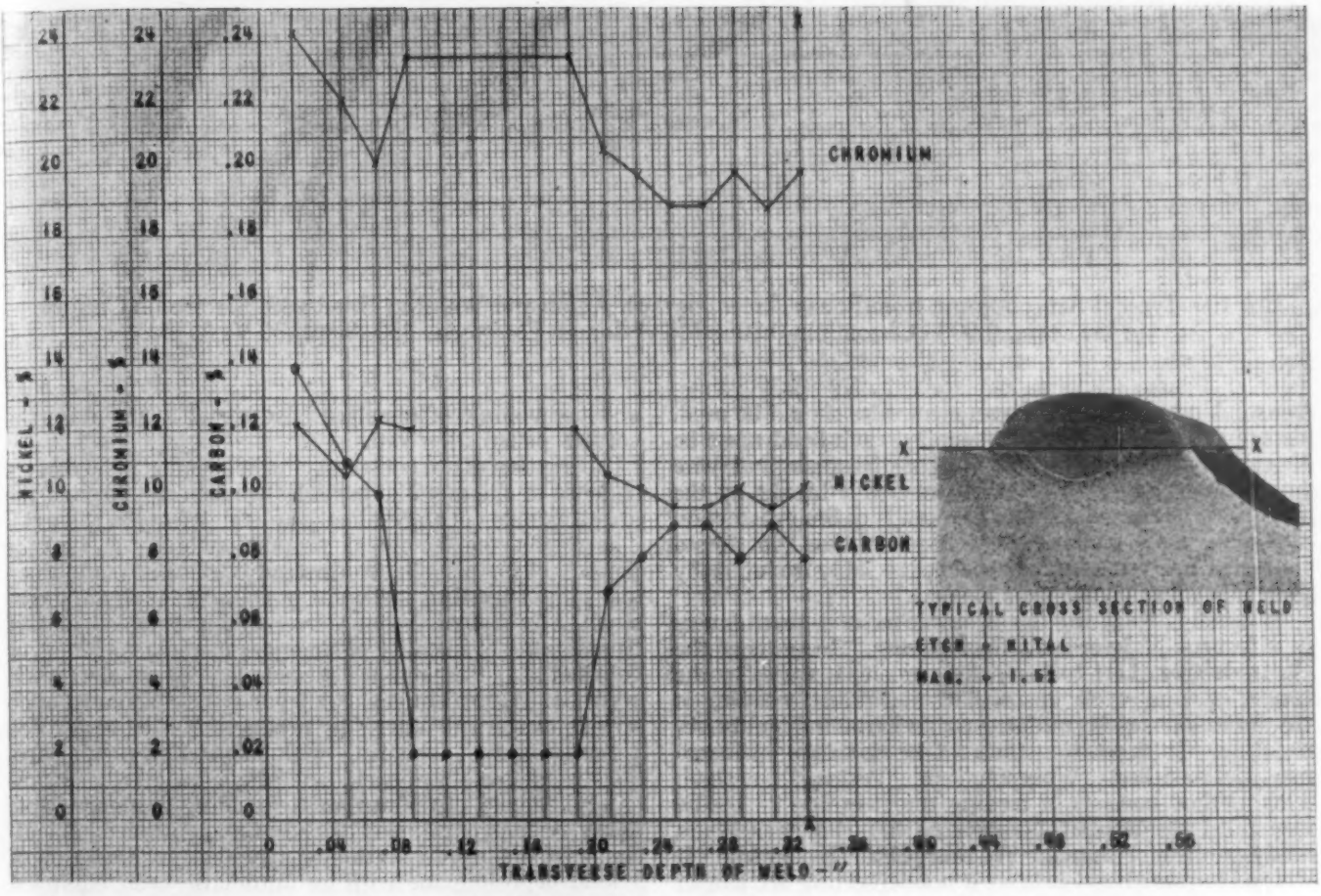


Fig. 8—Admixture of Single-Bead Deposit of A.I.S.I. Type 309 Submerged Arc Welded on Cast Carbon Steel

may be noted that practically the entire deposit conforms to the chemical specifications of A.I.S.I. Type 308. It is possible to closely control this process so that admixture may be held to a minimum or, conversely, the deposit may be diluted to a desired composition. Figure 9 illustrates the excellent bond that accompanies this method of arc welding facings. The combination of arc welding stainless steel facings to low-alloy disks and seat rings, coupled with the "Malcomizing" process, has resulted in valve seating surfaces highly satisfactory from the mechanical, metallurgical and economic view point.

The structural stability of the weld deposit has been given careful consideration. There are many commercial electrodes available today that contain both chromium and molybdenum, so that the composition of graphitization-resistant base metals may be duplicated in the weld deposit. Research work was conducted to ascertain the austenitic grain size and normality of the weld metal deposited by various types of electrodes. Since the hypothesis, "a coarse-grained normal structure, in the McQuaid-Ehn test, is more highly resistant to graphitization than a fine-grained abnormal structure," is generally accepted as true, efforts were made to insure that the deposit would always possess the former structure. Experiments indicated that the electrodes usually possessed a coarse-grained normal structure while the resulting deposit would be finer grained and quite abnormal. This condition was rectified by introducing a stream of an inert gas into the arc.

Welding Sequence

At the start of the actual welding operation, the laying in of the first bead must be performed with extreme care in order to obtain thorough fusion at the bottom of the joint. This location is one where gas pockets, cracks and slag are most likely to appear. Small rods should be used to lay in the first bead, and numerous small beads instead of one bead will produce a much better job. As

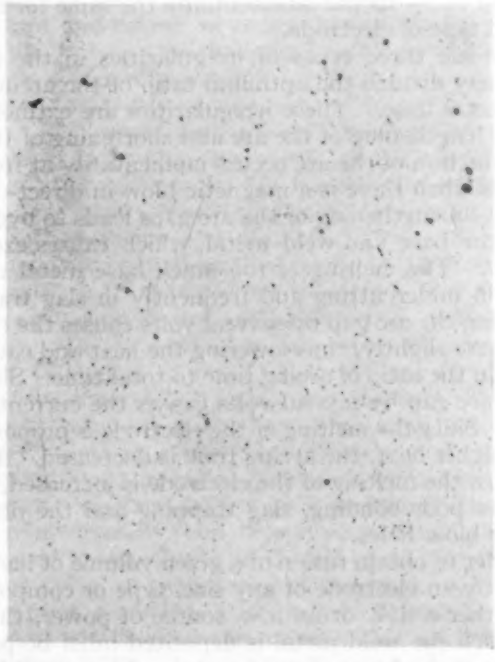


Fig. 9—Weld Junction, A.I.S.I. Type 309 Electrode Deposited on Cast Carbon Steel by Submerged Arc Method. Unetched. × 100

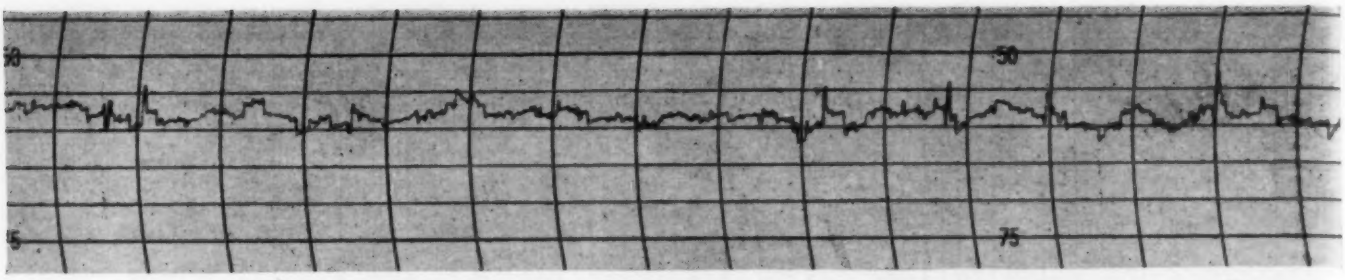


Fig. 10—Typical Arcronogram from Ronay Arcronograph Automatic Welding Head with Electronic Control, $^{3}/_{16}$ In. Diam. 0.50% Chromium-0.50% Molybdenum Electrode, 350 Amp., 30 V. A. C.

the work progresses, the larger electrodes should be used. Before subsequent beads are applied each bead must be thoroughly cleaned with a slagging hammer and wire brushed. Peening is very necessary as it breaks up the slag from the coated rod and also tends to limit distortion and subsequent cracking of the bead. It has been found that residual stresses may be appreciably reduced by proper peening of the weld deposit.

Manually depositing the electrode in subsequent layers in any type of joint calls for weaving. In moving the electrode from kerf to kerf, the arc length varies in the course of each cycle of oscillation. When weaving is rhythmic, the weld is uniform and free from under or over shooting. In depositing the root bead, many operators use the so-called "Whipping" or "Pecking" method. This method consists of feeding the electrode at a slow rate until the deposit becomes so hot that it appears ready to drop or bunch. At this point, the electrode is whipped upward and held at a nondepositing arc length to preheat the bottom of the groove ahead of the crater. During the preheating period, the deposit is allowed to chill and solidify, thereby preventing bunching or piling. Depositing at a normal arc length is again resumed and the procedure is repeated. Experienced operators recognize a definite rhythm, or cadence, in depositing the weld metal and they endeavor to maintain it. If this cadence is appreciably disturbed, the possibilities of making a dense, well-bonded joint is reduced in proportion to the magnitude and duration of the disturbance. This cadence, or ratio, should be essentially the same for a given size and type of electrode.

There are three types of irregularities in the stream which may disturb the optimum ratio of the arcing time to the total time. These irregularities are extinction of the arc, lengthening of the arc and shortening of the arc. The extinction of the arc occurs momentarily at frequent intervals when there is a magnetic blow in direct-current welding. Lengthening of the arc gaps leads to overheating of the base and weld metal, which causes excessive porosity. The melting of too much base metal usually results in undercutting and frequently in slag trapping. Increasing the arc gap by several volts causes the current to decrease slightly, thus lowering the heat and causing a change in the ratio of arcing time to total time. Shortening the arc gap by several volts causes the current to increase. Since the melting of the electrode is proportional to the higher heat, the arcing time is decreased. Due to high heat, the melting of the electrode is increased, which results in poor bonding, slag trapping and the development of blow holes.

In order to obtain fusion of a given volume of metal deposited by an electrode of any size, type or composition, using either a d.-c. or an a.-c. source of power, the area over which the weld metal is deposited must be proportional to the volume of weld metal. This condition involves a basic law that recognizes there must be a definite relation between the volume of the weld metal deposited and the volume of remelted base metal to maintain the correct penetration ratio.

Aberration of arc continuity, which changes the correct cadence of the metallic particles transferred through the arc stream, is apt to result in physical defects in the weld. The degree of damage is proportional to the time or period during which the unsteady arc was maintained and proportional to the value of the change in arc intensity. Any such disturbance over an appreciable length of time signifies possibility of a cavity, slag inclusion and/or coldshut. If the presence of such defects is isolated and occurs at irregular intervals, they may be considered of no serious concern. Where disturbances of the arc exceed 1 sec. in time, appearing with somewhat regular frequency, the resultant weld will prove defective. Fortunately, the use of the automatic welding heads available today circumvents most of the aforementioned difficulties. Figure 10 is a section of a typical Arcronogram of a weld deposit made with an automatic head equipped with an electronic control. The steadiness of the arc may be readily noted.

Stress Relief

In the development of the welded assembly, warpage, deformation and certain other types of trouble led to the

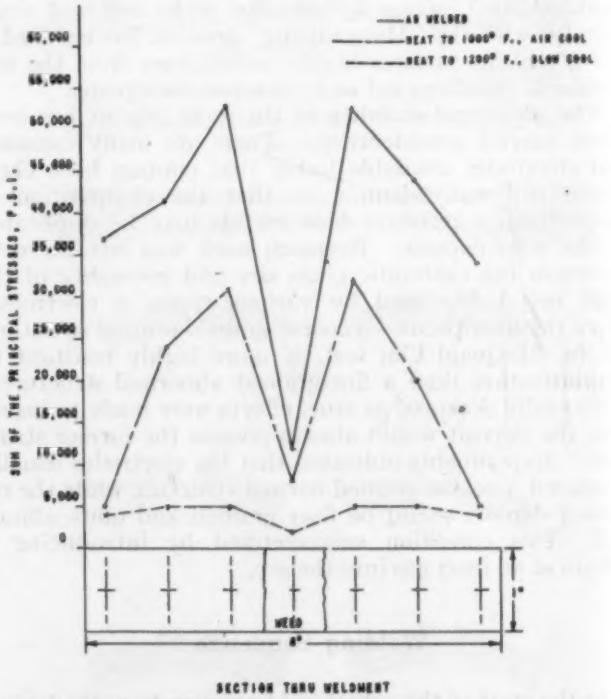


Fig. 11—Effectiveness of Various Stress-Relief Treatments, Butt Weld in A.S.T.M. A 217-45T Grade WC1 Cast Steel

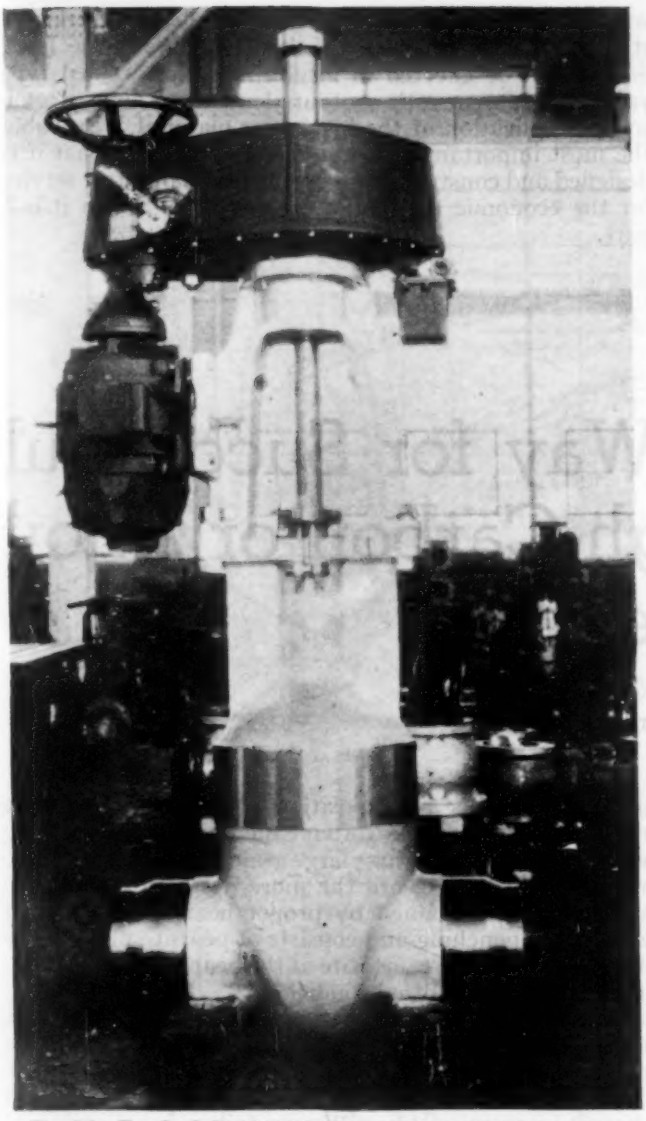


Fig. 12—Ten-Inch List 1500 W.E.O.S. Welded Body and Bonnet Joint Valve

institution of numerous investigations, which have proved stresses locked up in a metal following welding operations can be very serious in character. It is generally found impossible to entirely avoid such locked-up stresses, although in more ductile materials, the shrinkage stresses are not found to be so serious in their results. It is necessary, according to the A.S.M.E. code, to subject the completely welded assembly to some sort of heat treatment that will tend to relieve, or at least minimize, the intensity of these locked-up stresses.

The magnitude of these locked-up stresses depends on several elements, such as the size and number of welds, their position, preheat and other points in welding procedure. With the welding procedure previously outlined, these stresses are greatly reduced. However, any stresses left from welding are usually objectionable, and to avoid this, a form of heat treatment known as stress relief has been developed. This procedure involves heating the welded part to a uniform temperature between 1150 and 1250° F., and holding this temperature for a period of time. This temperature is held for 2 hr. for each inch thickness, of the thickest part welded, and the valve is then allowed to cool slowly by reducing the heat with insulating jackets in place until a temperature of at least 500° F. has been reached. Further cooling may be carried out in still air.

While it has been proved that heating a weldment to 1150–1250° F., followed by slow cooling, will result in practically 100% effective stress relief, this treatment has been modified after careful studies of the resistance of various structural constituents to graphitization. It has been proved that the rate of graphitization, in the weld heat-affected zone, may be affected by the postheat treatment. Increasing the postheat, or stress relief, temperature to just under the Ac_1 temperature was found to result in a slower rate of graphitization in laboratory samples aged at 1025° F. As a result of this observation, we have increased our postheat treatment to 1325° F. for welds in graphitization resistant, low-alloy steels.

It has been common practice to stress relieve an area, in annular sections, six times as wide as the weld thickness. We find, however, that holding full temperature on a band having an over-all width about twice the width of the weld is sufficient and this width is now used instead of six times the thickness of the weld. This width embraces the area of the metal which has the highest residual stresses. Restricting the width of the band heated to full stress relief operation is advantageous in that it avoids severe heating of the valve mechanism through excessive temperature gradients. The maximum point to point variation in surface temperature has been found to be within ±25° F., permitted in good heat treating.

Figure 11 illustrates the effect of stress relief on the residual stresses remaining in a welded section of cast-carbon molybdenum steel. The effect of various stress relief treatments on these stresses may be noted on the chart.

The stress relief temperature may be attained by means of resistance heating coils, induction heating, gas-fired furnaces, charcoal, etc. It is all-important that the temperature be uniform and the cooling very slow.

Quality of the Weld

For many years checking the quality of the deposited metal without applying some destructive test was impossible. In order to test a weld it was necessary to cut a sample out of a completed weld in the form of a full-size test specimen, removed either by trepanning or slotting. This form of test is still used on pilot welds for qualifying operators, and should, of course, be carried out at regular intervals, but new methods had to be developed for inspection of full size welds.

Various methods of nondestructive testing are used today. The most commonly used methods are magnetic particle, radiography, supersonic and sonic, fluorescent penetrant oil and visual. Each method of testing has its own advantages. Radiography is highly regarded since it is both sensitive and preserves a permanent record. The magnetic particle method readily detects surface and subsurface flaws that are not too deep. The two methods readily complement each other and a combination of the two represents excellent inspection of ferromagnetic welds. Welds in materials that are not ferromagnetic cannot be inspected by magnetic means. The fluorescent penetrant oil method must be substituted for the magnetic method. The visual inspection of a weld is all-important and there is no substitute for a highly trained inspector. Surface defects such as undercutting, excessive reinforcement, etc., are readily detected visually. The surface appearance of a weld gives the trained inspector a clue to the interior of the weld. The codes of the various standardization bodies define the required tests and it is beyond the scope of this paper to discuss them more fully.

Thus it may be seen that the modern valve is nothing more than a highly developed unfired pressure vessel.

Figure 12 shows a completed valve of the weld end, welded body and bonnet type. Welding has played a great part in the construction of the valve and we see here an example of things to come, the complementing of castings and weld fabrication. A valve of this type offers many advantages to the central station operator. An all-welded valve, of this type, weighs approximately 40% less than the conventional flanged joint type of valve. Appreciable savings can be effected by reducing the dead weight of the steam lines, since smaller hangers and structural steel work are required to support the lines. Saving can be effected in insulating an all-welded type valve since its smooth contours lend themselves readily to the application of the insulating material. Probably the most important advantage of this valve is that it is designed and constructed to give maintenance free service for the economic life of the equipment of which it is a part.

S-Curves Point the Way for Successful Welding of Any High-Carbon or Alloy Steel*

By Leo Berner†

S-CURVES have been developed for the purpose of efficient heat treatment of high-carbon and alloy steel. Many articles have been written covering the application of S-curves for heat-treating purposes, but little is available to teach the application of these S-curves for the specific process of preheating, intermediate heating and postheating of steels for crack-free welding, for which purpose the curves are ideally suited.

The difference in application is that for heat treating the curves show how the steel can be successfully hardened to any desired degree of hardness, whereas for welding they show how hardness can be avoided by proper control of the heat of the part to be welded, so that the weld will be free of dangerous locked-up stresses or cracks.

Those making use of these tables should have the metallurgical background that provides complete understanding as to how the curves have been established, what they show and how to use them. An attempt shall be made here to just give the highlights of the metallurgical foundation, together with the subject technical references, so that those not yet acquainted with these matters may get a rough over-all picture and, knowing the source, can read up on the references mentioned.

The S-curve, so called for shortness is correctly termed an Isothermal Transformation diagram showing the transformation of steel upon cooling after having been heated. Such cooling may either be natural, forced (quenching for heat treatment), or retarded (preheat, intermediate heating and postheating for welding).

An S-curve is made up from the data of over 100 individual test of small pieces of steel and is a tabulation of the transformation of the steel at various constant temperatures from face centered gamma iron, generally called austenite, to body centered alpha iron, which—depending on the rate of cooling and temperature at the time of transformation—may be pearlite, sorbite, troostite, bainite or martensite.

These various names of alpha iron are indicative of the steels' grain size, hardness and composition. For example, pearlite is a composition of ferrite (nearly pure iron) and iron carbide (often called cementite) varying from a fine to a very coarse large grain structure. Sorbite troostite and bainite are the more desirable finer grain size structures obtained by proper heat treatment and controlled quenching and consists of pearlite plus a variable amount of free cementite at the pearlite grain boundaries or in a spheroidized condition.

Martensite, however, is extremely hard and brittle due to its needle-like grain structure and, although desirable in certain cases of heat treatment, in view of its extreme hardness it is to be strictly avoided on any welding job where it unquestionably will cause failure in every case if it exceeds a certain percentage in the composition. Our job then is to control the heat of a piece to be welded so that only a possible minimum percentage of martensite is formed if it can not be entirely avoided.

Figure 1 shows the S-curve for S.A.E. 2340 steel. It should be noted here that each type of steel, for each varying degree of carbon or alloy content, requires its own particular curve. Furthermore, the curve is influenced also by the grain size, which may be different while the composition S.A.E. 2340 remains the same. The actual composition may also be slightly different from the nominal composition. These influences can, of course, change the shape of the curve, but the change will be small enough to omit consideration of them or they can be accounted for by extending the cooling time slightly, just to be on the safe side.

The particular curves shown, shaped like an "S," are based on a grain size 7–8, which has been austenitized at 1450° F. The temperature is indicated at the left vertical and the hardness in Rockwell C on the right vertical. The time in seconds is plotted on the bottom horizontal in a logarithmic scale. The curve marked *TB* indicates the beginning of the transformation of austenite and curve *TE* shows the end of the transformation without any trace of martensite.

The curve *TM* at the bottom is not usually shown in the diagrams, but is only assumed and therefore is not correct (no data available). It is based on the fact that martensite actually does not form until the steel tempera-

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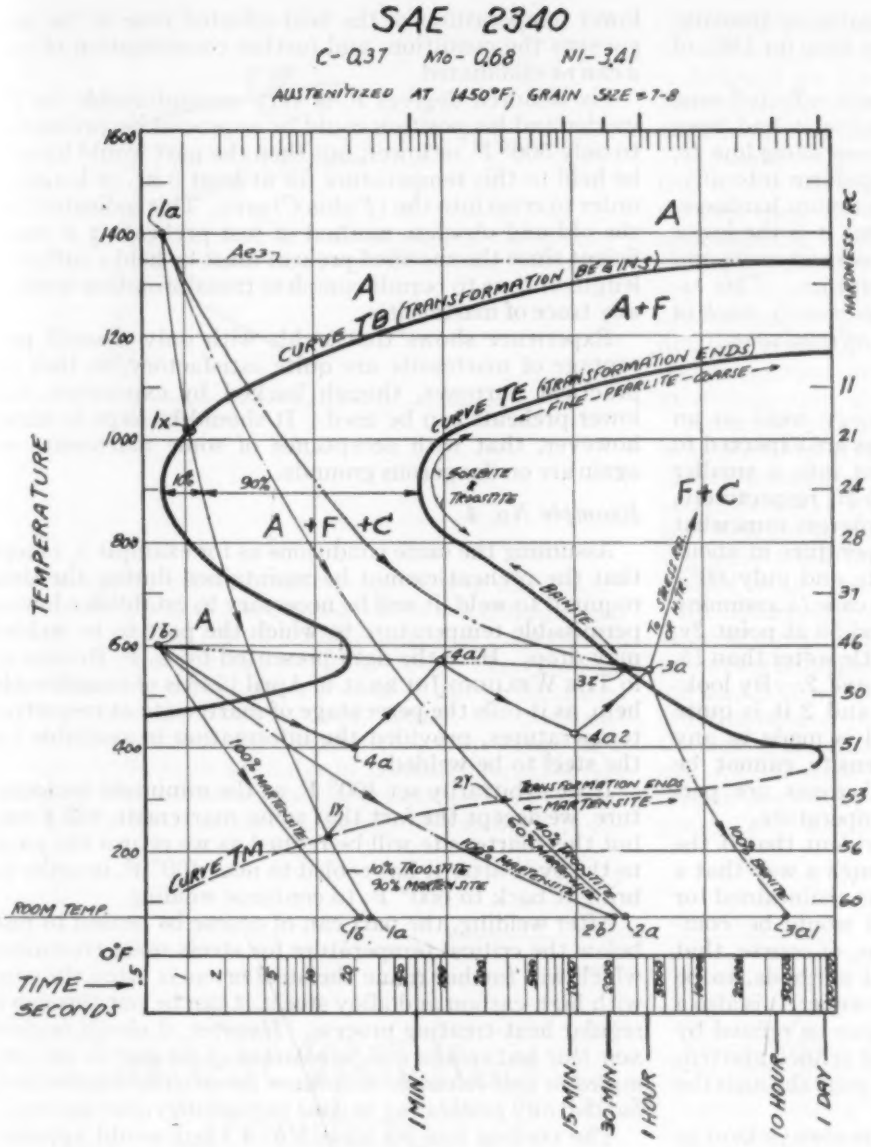

Fig. 1

ture reaches the neighborhood of 200° F. upon cooling. The curve *TM* has here been added only to illustrate this fact and to provide a rough and inaccurate measure of hardness of the martensite along this curve.

All that is known at this time is that there is more hardness in martensite due to a quick quench and less on retarded cooling, depending on the temperature at which the martensite forms. Otherwise there is no benefit to be gained from this curve. The fact whether and how much martensite will be formed is determined by the cooling line contact with curves *TE* and *TB* and the amount of transformation does not change when the cooling line contacts curve *TM*, but transformation itself does take place at the *TM* curve. The amount of martensite is determined by the per cent of penetration of the cooling line on a horizontal between curves *TB* and *TE* as will be shown later.

While the writer was working on this article THE WELDING JOURNAL of April 1946, published a very excellent discussion on the subject by L. F. Browne, who also in great detail explains the difficulty in establishing curves below 500° F., and who establishes the per cent of martensite not on the horizontal between the curves *TB* and *TE*, but on the vertical parallel to the temperature scale. This indicates that authorities are still working on the completion of the lower parts of the S-curves, but that such investigation must come from the welding field.

The area to the left and above curve *TB* consists of austenite marked *A* and is expected to transform upon cooling. The area between curves *TB* and *TE* consists of the stage of transformation with austenite and ferrite (*A* plus *F*) in the upper part and austenite, ferrite and cementite (*A* plus *F* plus *C*) in the lower part. The austenitic gamma iron *A* in this area if not transformed completely into alpha iron (*F* plus *C*) cools to something between gamma and alpha or face and body centered iron, or we can say the transformation was arrested by fast cooling before completion, resulting in the transformation of the remaining austenite into martensite. Limited within this area fast cooling will produce more martensite, slow cooling less, as will be illustrated later.

The area to the right of curve *TE* contains no more austenite and what to us is of greatest importance contains no martensite, but consists of only ferrite and cementite (*FC*).

It will be noticed from the Rockwell Hardness table that the hardness increases from coarse and soft pearlite, through fine pearlite, sorbite, fine and very hard bainite to extremely hard martensite. Coarse pearlite, having been held longer at higher temperature permitting grain enlargement, is undesirable in view of its lowered strength due to its large grains.

Historically the first S-curve was published in 1930 and was developed by Dr. E. C. Bain and E. S. Davenport, both of the U. S. Steel Corp., who in 1943 finally collected most of the available curves for publication in one volume, namely the Atlas of Isothermal Transformation Diagrams, showing 56 diagrams of 47 different compositions with a very understandable and thorough discussion, in addition to a complete bibliography on the subject on page 15. However, considering a special welding interest, THE WELDING JOURNAL of April 1946, on page 234-s published a very good article on the subject while the writer's article was still in production.

For further study from a welding point of view, a book by O. H. Henry and G. E. Claussen entitled Welding Metallurgy is recommended. With this rough and very sketchy metallurgical foundation settled, we can go on to some practical examples as encountered in welding.

Welding Examples

Example No. 1

Case A.—Choosing the extreme case of a light weld on a very massive piece of steel the heat-affected zone, heated to above the critical temperature Ae3 (say 1400° F.) can be assumed to be cooling so fast as to be in fact a fast quench along line *1a*, cooling to room temperature in about 25 sec. The line crosses the *TB* curve at point *1x* and just barely enters the nose of the curve. Upon cooling the part will consist of about 10% ferrite and ce-

mentite (*F* plus *C*) in the form of fine pearlite or troostite and 90% martensite since there was only time for 10% of the austenite to transform.

Case B—Investigating a part of the heat-affected zone farther away from the weld and assuming it had been heated to only 600° F., it would cool slower along line *1b*, but would have no chance at all to transform into anything else but 100% martensite with maximum hardness.

Notice should be taken of the fact that it is the lower temperature of case *1b* that produces more martensite and is therefore the more dangerous temperature. *This explains the fact that such a weld will not necessarily crack in the weld itself, but outside of it in the heat-affected zone.*

Example No 2

Choosing the case of an average heavy weld on an average size steel, the heat-affected zones are expected to cool slower due to a greater heat input into a smaller mass and the cooling line *1a-2a* and *1b-2b*, respectively, corresponding to lines *1a* and *1b*, will progress somewhat as indicated when cooling to room temperature in about 35 min. *2a* now ends in 40% troostite and only 60% martensite, which is not quite as hard as case *1a* assuming the hardness to be 55 RC at point *1y* and 53 at point *2y*. Line *2b* still ends in 100% martensite, little softer than *1b*.

Conclusions Formed from Examples 1 and 2.—By looking at the cooling lines of examples 1 and 2 it is quite evident that no matter what size weld is made in any mass of steel the formation of martensite cannot be avoided if the weld and heat-affected zones are permitted to cool uncontrolled to room temperature.

On the other hand, it is also quite evident that if the steel to be welded were to be heated in such a way that a minimum temperature of way 600° F. is maintained for at least 2 hr. after welding, the steel would be completely free of martensite. It is obvious, of course, that this cannot always be done, and several methods, to be discussed later, suggest themselves. However, it is also a well-known fact that while martensite can be refined by subsequent heat treatment, even the best refined martensite is not as good as steel that has never gone through the martensitic state.

This consideration should therefore be always kept in mind when evolving processes for the welding of steels subject to martensite formation and in line with this, the following example No. 3 is suggested as the process with the best results.

Example No. 3

The part to be welded can be preheated to 600° F. and it is assumed that during the time required for welding the part will get sufficient additional heat from the arc to nearly maintain his temperature of 600° F., or that a steady extra source of heat is supplied during welding for at least 1 hr. Again investigating the same two points in the heat-affected zone of the weld, one at 600° F., the other at 1400° F., the cooling lines would approximately progress as indicated by line *1a-3a-3a1* for case *3a* and along line *1b-3a-3a1* for case *3b* if the part is permitted to cool after point *3a* has been reached. It will be noticed that both cooling lines *a* and *b* cross curve *TB* and then at point *3z* pass curve *TE* for a complete transformation into bainite

The fact that the combined cooling lines *3a-3a1* again pass curve *TE* and also cross over the disputable curve *TM* is of no consequence, since the transformation of the steel was completed at point *3z*. The hardness of the steel would be approximately 48 RC. The cooling line *1a-3a* may, of course, reach line *1b-3a* to the left of point *3z* or possibly to the left of *3a*, but that is also of no consequence since it could never fall below the cooling line *1b-3a*. In other words, this case again illustrates that the lower temperatures of the heat-affected zone in the steel governs the condition, and further consideration of case *a* can be eliminated.

Six hundred degrees F. is very uncomfortable for the welder and his position could be improved by preheating to only 500° F. or lower, but then the part would have to be held to this temperature for at least 3 hr. or longer in order to cross into the (*F* plus *C*) area. This indicates that the old and obsolete method of just preheating is insufficient since the specified preheat must be held a sufficient length of time to permit complete transformation without any trace of martensite.

Experience shows that welds with only a small percentage of martensite are quite satisfactory, so that for practical purposes, though backed by experience, still lower preheats can be used. It should be kept in mind, however, that with acceptance of some martensite we again are on dangerous grounds.

Example No. 4

Assuming the same conditions as for example 3, except that the preheat cannot be maintained during the time required to weld, it will be necessary to establish a lowest permissible temperature to which the part to be welded may drop. Here the data presented by L. F. Browne in in THE WELDING JOURNAL of April 1946 is of considerable help, as it tells the percentage of martensite at respective temperatures, provided the information is available for the steel to be welded.

If we arbitrarily set 400° F. as the minimum temperature, we accept the fact that some martensite will form, but this martensite will be refined as we return the piece to the oven after it has cooled to near 400° F. in order to bring it back to 600° F. to continue welding.

After welding, the part can of course be heated to just below the critical temperature for stress relief treatment which will further refine the steel or, as is often the case with high-carbon and alloy steels, it can be put through a regular heat-treating process. *However, it should be clear now that best results will be obtained if the part is not permitted to cool below the minimum permissible temperature, but that any postheating be done immediately after welding.*

The cooling line for case No. 4 then would approximately progress as shown by line *1b-4a-4a1-4a2-3a* and *3a1* indicating a preheat to 600° F. at *1b*, loss of heat to *4a* and *4a2*, respectively, during welding and two intermediate reheats from *4a* to *4a1* and *4a2* to *3a*, respectively, to restore the preheat to 600° F. After point *3a* is reached, transformation is complete and the weldment can cool off to *3a1*, but if stress relief or heat treatment is to follow it should set in at the point where welding is completed, say at *4a2*, and extending beyond line *4a2-3a* to whatever top temperature the treatment calls for.

While the line *4a-4a1* is a true intermediate heat, the heat line *4a2-3a* is often called a *post heat* since it takes place after welding is completed and in order to complete transformation by forcing the heatline to cross over the *TE* curve into the bainite area.

Intermediate heats are, of course, not always necessary. If welding could be completed, say at *4a*, the heat line would run from *1b* to *4a* with a postheat to *4a1*, and then holding this heat straight across to *3a*, *4a2* could be avoided entirely. Thus one complete furnace cycle has been eliminated since only a preheat and a postheat are required.

Conclusion

All of the above constitutes but a general review of the subject from a practical point of view. It is by no means meant to be anything else, except to possibly induce fur-

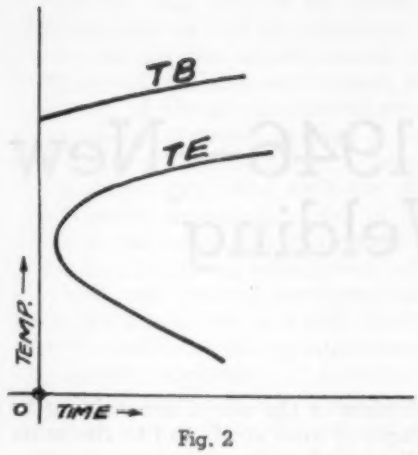

Fig. 2

ther research by our authorities, especially in the still unsettled lower parts of the curve. There is a definite need for that, as well as for additional diagrams to cover the full range of commercially available steels. Steel makers, when furnishing steel heat test data to their customers, should include an S-curve. And, finally, the pertinent data developed from the diagram to set up examples 3 and 4 should be made available in tabulated form for fast and ready reference similar to the present preheat tabulations, which, in other words, should be extended to include minimum permissible temperatures and lengths of time at which the top temperature is to be held.

Although we have made reference only to welding, it is understood that what has been said holds equally true for flame burning or any other process applying heat to the steel.

It may be of general interest to include mild steel into this review with a particular reference to the S-curves, because these curves at a glance show why mild steel is nonhardening and therefore so readily weldable. For mild steel the *TB* curve (Fig. 2) completely penetrates into the left-hand vertical of 0 sec. and the *TE* curve approaches so closely to this vertical that even the most drastic quench of only a second or two permits complete transformation into a pearlitic structure without any martensite and only very little increased hardness.

However, as a general rule, the limit of such welcome behavior of mild steel for welding is quickly reached at a carbon content of about 0.30% if no alloys are present and of only 0.15% carbon if alloying elements are present. But with the help of S-curves the welding of high-carbon and alloy steels no longer needs to be feared and can be carried to any limit.

In closing, it should be noted that until complete tabulated information becomes available, the advice of a competent metallurgist should be solicited in setting up heating and cooling procedures. This advice is essential in order to reduce oven time to a minimum and to arrive at the best grain structure, since there are many deviations and special considerations to be made with respect to certain high-alloy steels, such as stainless, high manganese, etc., which could not possibly be covered here.

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(*Continued on page 120*)

Adams Lecture for 1946—New Frontiers in Welding*

By Wendell F. Hess†

WE ARE met here this evening to honor Dr. Comfort A. Adams, first president of the AMERICAN WELDING SOCIETY, present Honorary Director and Chairman of the Welding Research Council. It is our purpose to discuss some of the more notable advances which have been made in recent years as a result of research and development in the field of welding, and which now offer limitless opportunities for future applications in the field of manufacture and construction. Charles F. Kettering has said, "Where there is an open mind, there will always be a frontier." The enthusiastic encouragement, keen interest and open-minded attitude of Dr. Adams have gone far toward providing the proper approach and atmosphere for successful accomplishments in the various fields of welding research and development.

Although welding had made important advances between the two World Wars, both development and application proceeded at an increased tempo during World War II as a result of Government-sponsored research and the war production effort. Experience gained from these researches and from the extensive war application of welding have indicated new and fruitful frontiers for the application of welding, as well as other new frontiers for exploration and research. Progress in these new fields of research in welding will inevitably lead to even greater opportunities for the entire welding industry. The general benefit to the industrial economy provided by the intensive cultivation and development of these frontiers of application and exploration, will go far toward raising the standard of living and increasing the freedom of all peoples.

The pace of welding development has been so rapid that it is not to be expected that all of these developments can be discussed within the compass of this single brief lecture. It is hoped that the reader will pardon the tendency to dwell in greater detail on those developments with which the writer has been most closely associated. The length of the discussion of the different items therefore is not to be construed as a measure of the importance of the development.

New frontiers for the immediate and future application of welding have been made possible by the following factors:

1. Increased knowledge of the cooling rates associated with arc welding and of the metallurgy of the welding processes.
2. Newer knowledge of the factors affecting cracking and of the magnitude of residual stresses produced in arc welding.
3. Extensive development of electric resistance spot welding of the structural aluminum and magnesium alloys.
4. Extension of the use of spot welding to the hardenable steels, and to the heavier gages of structural plates and shapes.
5. Extension of the use of arc welding to the thinner gages of mild steel, and to the more hardenable alloy steels in heavier gages.
6. The development of new equipment having improved characteristics with regards to power supply, speed of welding, and quality of product.

Many of the factors mentioned above have been the result of the development of new instrumentation for the measurement of welding variables, and new techniques for the control and evaluation of weld quality. The factors mentioned above will be discussed in the following paragraphs.

Arc Weld Cooling Rates.—Careful quantitative studies[1,2] of the cooling rates associated with arc welding and of their relationship to the known welding variables, have made it possible to control the metallurgical structure and associated mechanical properties of the metal immediately adjacent to an arc weld. Arc weld cooling rates are determined by electrical energy input to the arc per unit length of weld, plate thickness, plate temperature, and joint geometry. The electrical energy input to the arc is a simple function of arc voltage, arc current and travel speed. The cooling rates associated with arc welding have been experimentally measured by thermo-couples located so as to record the maximum cooling rates associated with a particular set of welding conditions. To obtain a reasonably complete coverage of the different welding variables would involve an almost interminable amount of experimental work. Fortunately, a mathematical equation based on thermal properties of the steel and some of the welding variables mentioned above, may be established. The mathematical equations must be set up either on the assumption of a thin plate which is heated throughout its thickness and cooled only by conduction in a lateral direction, or else on the basis of a plate of infinite thickness in which cooling takes place in all possible directions within the plate in a plane perpendicular to the direction of welding. Thus, although the mathematical solution is capable of taking into account the thermal properties of the steel, the effect of plate temperature, and the effect of weld energy input, the mathematical solution cannot take care of the finite thickness of the plate which is being welded. The mathematics is also subject to a further limitation based on the necessity of assuming that the energy is delivered at a point source rather than to a pool of molten metal, which acts as a distributed heat source. It is interesting to note that this distributed heat source provided by the travelling pool of molten metal, results in somewhat slower cooling rates than would be produced if the heat were actually delivered from a point source. Another way of stating this relationship is that the distributed heat source acts as though more than the actual amount of power were being delivered to the arc. The mathematical solutions may be made to actually fit the observed cooling rates by evaluating certain coefficients which may be introduced

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into the equations to take care of the differences between the actual conditions and the assumptions which were necessary to set up the mathematical equations. Once these coefficients have been established, it becomes possible to make use of the mathematical equations to provide a tremendously increased amount of data giving the energy input required to produce any desired cooling rate at any temperature level, and with any given plate temperature and joint geometry. One of the coefficients introduced in the mathematical equations might be said to express the "degree of infiniteness" of the plate thickness, since with one limit of its value the equation becomes the thin plate solution, and with the other limit of the value of this coefficient the equation becomes that for the plate of infinite thickness. It is very interesting to note that with ordinary welding conditions, the one-half inch plate thickness in butt welding becomes essentially a thin plate as far as the mathematics is concerned. On the other hand a plate of one inch thickness, in the usual range of welding conditions, becomes essentially a plate of infinite thickness. The conditions experimentally determined for $1^1/_2$-in. plate are thus only slightly different from those obtained for the 1-in. plate thickness. This is a very important circumstance since it permits the data obtained on $1^1/_2$-in. plate to be used for all plate thicknesses heavier than this. The behavior of $^1/_2$-in. and 1-in. plates mentioned above, comes about through the circumstance that only the cooling rates through certain temperature ranges in which metallurgical changes may take place, are important in welding. In the case of $^1/_2$-in. plate, by the time the metal cools to the temperature range of elevated temperature transformation, heat has travelled through the thickness of the plate to the opposite surface and has been reflected back to significantly arrest the cooling of the zone adjacent to the weld. On the other hand, in the case of 1-in. plate, by the time the zone adjacent to the weld has cooled to the range for elevated temperature transformation, heat is still flowing toward the opposite surface of the plate and the cooling rate is not appreciably affected. It is of further interest to note here that the mathematical solutions actually pointed the way to the proper explanation of the observed differences in cooling rate experienced on the various plate thicknesses studied, namely $^1/_2$ in., 1 in., and $1^1/_2$ in.

The ability to control the cooling rates produced by arc welding, if it is to be applied to the control of metallurgical structures produced in welding, involves also a study of the response of the particular steel being welded to a variety of cooling rates. The response as regards hardness and general type of metallurgical structure may be evaluated by means of a Jominy hardenability test. By general type of metallurgical structure it is meant that the Jominy curve will indicate whether the transformation has been martensitic, or largely elevated temperature transformation, or whether a split transformation has occurred, with part of the structure transformed at elevated temperatures and the remainder at low temperatures. The Jominy bar has been calibrated with reference to cooling rates at various temperature levels for each position along the bar. Instead of relying upon the general type of metallurgical structure indicated by the Jominy bar, as a basis of controlling welding conditions to produce desired ductility, it is possible, using hardness as an index, to make additional tests of a particular steel to determine its ductility as a function of hardness produced by continuous cooling.

In another series of studies[3,4] of the effect of welding conditions on the properties of the metal adjacent to the weld, hardness was used as an index of cooling rate, and the welding conditions necessary to reproduce the cooling rates found at various points along the Jominy bar were determined. In applying either of these systems for determining welding conditions to be used, one of the first steps is to determine the position on the Jominy bar which it is desired to reproduce in the zone adjacent to the weld. Unfortunately, there is a rather wide divergence in the predictions determined by these two systems. It is to be noted also that in the studies involving the use of hardness as an index rather than direct measurements of cooling rate, it was not discovered that there was a particularly significant difference in the behavior of $^1/_2$-in. and 1-in. plates, and that $1^1/_2$-in. plates behaved very nearly the same as one-inch plates, in accordance with the concept of degree of infiniteness of the plate mentioned above. The difference in the conditions prescribed by the two systems is particularly marked in the cases where preheat of the plates is employed and where the Jominy distances are in the range from $^1/_2$ in. to 1 in. These are the distances where the precision based on hardness as an index would be expected to be low with the plain carbon steel SAE 1035, which was the steel principally used in establishing the relationships between welding conditions and position on the Jominy bar.

In using the Jominy bar as an index of proper welding conditions, it is important to realize that the transformation at a given point on the Jominy bar, if we are considering the low hardness or elevated temperature transformation portion of the curve, may have occurred at different temperature levels depending upon the type of steel. Thus, it is important to determine, from an inspection of an isothermal transformation diagram, the temperature range in which elevated temperature transformation may be expected to occur. It is then necessary to determine the Jominy cooling rate in this temperature range for the establishment of the proper welding conditions. For this purpose, the Jominy bar has been calibrated for cooling rates through different temperature ranges.

The importance of determining the temperature range in which transformation may be expected to occur for a particular steel, is due to the fact that welds in the various plate thicknesses of steel do not cool with similar curves to that of the Jominy bar, through different ranges of temperature. Thus, when a position on a Jominy bar is selected, it is important to know the temperature range in which the structure was produced, if the proper welding conditions to reproduce that structure are to be determined. It is of interest to note that a 1-in. plate at room temperature cools most nearly in the same manner as a Jominy bar throughout the possible range of elevated temperature transformation for different steels. Heavier than 1-in. plate, such as a $1^1/_2$-in. plate, also cools in a manner quite similar to a Jominy bar when the plate is at a temperature of 75° F. On the other hand, a $^1/_2$-in. plate at room temperature cooled in quite a different manner than a Jominy bar through the possible range for elevated temperature transformation. This effect is particularly true the farther out on the Jominy bar is the position selected to be reproduced by welding. In the range from about 0.2 to 0.4 inch distance on the Jominy bar, for the $^1/_2$-in. plate at room temperature, the weld cooling curve is very similar to that experienced on the Jominy bar. For positions on the Jominy bar beyond 0.5 in., the cooling curves through the elevated temperature ranges depart more and more from the condition on the Jominy bar. Preheat of the plates causes an even greater difference between the manner of cooling of the steel plate and the Jominy bar. This condition is true on all plate thicknesses. These remarks are intended to emphasize the fact that whereas a Jominy bar may be cooling at the same rate as a zone adjacent

to a weld in a steel plate, at a temperature of 1300° F., it is not necessarily true that the Jominy bar and the steel plate will be cooling at the same rate at a lower temperature of subcritical transformation, such as 800° F. or 1000° F.

Further knowledge of the metallurgy of the welding processes has come from the experience of graphitization of elevated temperature piping. The studies of the phenomenon have indicated the effect of the heat of the welding arc in certain steels in causing redistribution and precipitation of the carbon, thus rendering the steel susceptible to graphitization as a result of elevated temperature service. Graphitic segregation, sufficiently continuous to cause failure of the pipe in service, has been found at the outer edge of the heat-affected zone in the region of spheroidization. The graphitization studies have pointed the way to the correction of this difficulty through better selection of steels for new installations, and to a possible treatment for existing installations which are susceptible to graphitization as a result of continued elevated temperature service.

Still other knowledge of the metallurgy of arc welding as it concerns the effect of the welding heat on the zone outside of that which has been transformed by the heat of welding, is the study of the effect of temperature on the notch sensitivity of different regions of the weld heat-affected zone. The extremely fine spheroidization, visible only at very high magnification, which takes place as a result of brief exposure to temperatures just below those required to cause re-crystallization as a result of transformation, appears to adversely affect the notch sensitivity characteristics of the steel by raising the transition temperature range, for change from ductile to brittle fracture in the Charpy-Izod specimen.

Cracking and Residual Stresses.—The cracking of welds during the fabrication of structures is the result of weld metal shrinkage in building up residual stresses of sufficiently high magnitude. The cracking tendency is accentuated by any condition which tends to permit a limited cross section of deposited metal to withstand the contraction of the weld and adjacent heated zones, or any factor which tends to increase the restraint against contraction of the weld, imposed by the structure. Other factors which tend to produce embrittlement in the region immediately adjacent to the weld, also tend to limit contraction and thus build up stress, and may cause either weld metal or base metal cracking. As examples of the conditions mentioned above, the leaving of unfilled craters is a conspicuous and frequent cause of weld metal cracking. Lack of proper fusion at the base of a notch in a vee or groove weld, tends to introduce a notch effect at the critical section of the deposited metal and thus to make cracking more likely to occur. The use of a low value of energy input, deposited by an electrode having tendency to produce concave surface contour, also predisposes toward weld metal cracking. The thickness of plate, sequence of welding, and the geometry of the structure, may each contribute sufficient additional restraint of weld contraction to cause cracking. The embrittlement of hardenable steels caused by welding with improperly controlled cooling rate, also favors cracking of either the weld metal or base metal. Base metal cracking has been found to be definitely accentuated when electrodes are used which tend to introduce large volumes of hydrogen gas into the arc stream. These latter conditions are of importance principally in the case of hardenable steels. The possibility of greatly reducing the cracking tendency in the base metal by avoidance of the introduction of hydrogen into the arc stream, opens up an entire new field for the arc welding of high strength structural steels. The possibility of avoiding under bead cracking in these steels, makes possible subsequent heat treating of the entire structure to improve the properties of the weld heat-affected zone. In some cases the tempering effect of successive weld passes is sufficient to produce satisfactory properties in the weld and adjacent heat-affected zone. Another embrittling effect which is a frequent cause of difficulty in the welding of plain carbon steels is that caused by low temperature. When welding is conducted at low temperatures, due to adverse atmospheric conditions, it is not the increased cooling rate brought about by these low temperatures which causes difficulty in the matter of weld and adjacent metal cracking, but rather the increased notch sensitivity or loss of toughness, which is suffered by these steels as a result of reduction of temperature. Thus, whether or not to weld at low temperatures depends on the particular steel under consideration, as a result of its low temperature notch sensitivity.

Quantitative knowledge of the magnitude of the residual stresses produced in arc welding has been greatly extended in recent years.[12] This together with knowledge of the relationship of different welding variables to the magnitude of the resulting residual stresses permits an intelligent approach to the problem of residual stresses in welded structures. Recent studies[13] have shown that longitudinal restraint is sufficient to produce residual stresses approaching the yield strength of the metal when a weld having a length of 18 inches or more is made between plates of the order of one inch in thickness. It has been shown that stresses of this magnitude exist after the deposition of only one pass of a multipass weld. It has also been shown that very appreciable reduction in these longitudinal residual stresses may be made by preheating the plates, and maintaining the preheat temperature until the weld has cooled to the temperature of the surrounding plate. Transverse stresses of high magnitude exist at the center of the weld but decrease rapidly with distance away from the weld unless the plates are restrained against transverse contraction of the weld. Transverse stresses built up under the effect of transverse restraint increase in almost uniform increments for each pass of a multipass weld deposited with the same value of energy input. The stress increments per pass are not linear with energy input. Thus it becomes possible to fill a weld groove under severe conditions of transverse restraint, by the application of a relatively large number of small weld passes, with resulting lower total magnitude of transverse stress than when the same weld is completed by a smaller number of passes of larger value of weld energy input. The combination of plate preheat to reduce longitudinal residual stresses, together with passes of low value of energy input to reduce transverse stresses, makes an excellent combination for rewelding local areas in heavy plate vessels which have been chipped out for re-welding as a consequence of the discovery of internal flaws in the X-ray examination. This combination is also satisfactory from a metallurgical viewpoint, in that the tendency of the welds made at low value of energy input to produce severe cooling rates with consequent hardening of the metal adjacent to the weld, is counteracted by the effect of the preheat temperature. The rather extensive series of reports[12–18] on the subject of residual stresses in welded structures, which have recently been published, should be carefully studied by everyone interested in the problem of weld stresses, since a number of other relationships may be seen, such as the effect of various specialized techniques designed to minimize residual stresses or distortion.

Aluminum Alloy Spot Welding.—Recent extensive investigations in this field,[19–22] have shown the important factors which must be controlled if satisfactory consistency and quality of spot welds for use in the primary

structures of aircraft are to be produced. One of the essential considerations for this type of welding is proper preparation of the surface to be spot-welded. This is necessary because of the unsatisfactorily high resistance found on stock as it is ordinarily received from the mill. Although this high electrical surface contact resistance may be removed by mechanical cleaning either with a wire brush or with abrasive materials, it is usually preferable to remove the oxide film by chemical action. This is particularly true when large amounts of material are to be treated and the equipment required for a satisfactory chemical surface preparation may therefore be justified. Equipment for the rapid and convenient measurement of electrical surface contact resistance of these materials is very important if satisfactory quality control is to be maintained.

Due principally to the high thermal coefficient of expansion of aluminum alloys, difficulty may be experienced in producing sound welds free from internal cracking, unless proper precautions are exercised. The presence of cracks in the ordinary tension shear type of joint, is less important than when spot welds are located in sheets bearing stresses which are not transmitted through the spot welds. In the latter case, the presence of cracked spot welds will cause a serious loss in ductility of the sheet material, together with an appreciable reduction in fatigue strength. When welding the clad structural aluminum alloys using alternating current equipment, cracking may be avoided by use of sufficiently long welding time to heat the metal surrounding the weld. Subsequent contraction of this heated metal around the weld tends to prevent building up sufficiently high stresses within the weld area to cause cracking. In the case of the short time condenser discharge welding of structural aluminum alloys, it is practically impossible to provide welding conditions which will avoid cracking, if a constant pressure is applied by the machine. The avoidness of cracking is rendered sufficiently less critical to be perfectly possible of attainment in production if a double pressure condenser-discharge welding machine is used. This consists of welding at low pressure followed by the application of a high pressure. The use of the double pressure system in connection with aluminum spot-welding machines of the condenser-discharge type, entails careful adjustment of the relationship between current wave form and time of application of the forging pressure. The forging pressure must not be applied before the peak value of welding current has been reached, since the premature application of pressure will prevent the complete formation of the spot weld of desired size. If on the other hand, the forging pressure is applied too late, it will be ineffective in preventing formation of cracks. If consistent spot welds of the structural aluminum alloys are to be obtained, careful attention must also be directed to the production and maintenance of a desirable tip contour. If maximum consistency is to be obtained, welding current and pressure must also be adjusted to make welds on the flat upper portions of the strength-current characteristics.

In view of the expected surplus of aluminum alloy materials, some attention has been devoted by manufacturers to the substitution of sheet aluminum for other applications than aircraft spot welding. In many of these items, the cost of fabrication is an important consideration and must be kept as low as possible. This results in a tendency to attempt to weld the aluminum alloys without surface preparation. When this is done, trouble is usually experienced with sticking of the electrode tips to the work surface, and badly burned and unsightly spot welds are produced. It is quite possible that at some time in the future, when the attention of aluminum producers is directed to the more widespread introduction of aluminum sheet materials into ordinary non-stressed types of welded fabrication, the producing companies of the aluminum alloy sheet may be led to provide sheet for spot welding having an electrical surface contact resistance of suitable magnitude for immediate processing by spot welding, without the necessity for preliminary surface preparation in the shop. It appears definitely possible to process sheet material at the mill, and to maintain a satisfactory surface for spot welding by a very light oiling of the sheet surface after preparation at the mill and until the proper time for spot welding in the customer's plant.

The application of spot welding to the stressed structures of aluminum alloy aircraft has only begun to scratch the surface of the possible applications in this field. This is particularly true in the commercial types of planes and represents a practice resulting from the quality of spot welding which could be produced in production a few years ago, before extensive developments made possible the quality control of spot welds in these materials to a highly satisfactory degree. It may now be said with complete assurance that electric resistance spot welding of structural aluminum alloys is ready to be applied to the most difficult problems in this field, which certainly appears to offer one of the most fruitful frontiers of application for welding.

Magnesium Alloy Spot Welding.—When it becomes desirable to fabricate magnesium alloy structures by spot welding, it will be found that a large part of the necessary development of the spot welding process for these alloys has already been carried out, and that reports are available describing this work. With the comparatively hard non-clad surfaces of the structural magnesium alloys, spot weld surface preparation has usually been accomplished by mechanical abrasive cleaning. Wire brushing does not produce the proper surface for spot welding. Part of the rather extensive research already undertaken in the spot welding of magnesium alloys has been directed toward developing methods of chemical surface preparation. When spot welding the lower strength magnesium-manganese alloy, considerable difficulty has been experienced in the matter of sticking of the electrodes to the work. Continuous welding under these conditions results in excessive burning of the sheet surfaces, which does not result in satisfactory welds. This condition necessitates the frequent removal of electrode tips for re-dressing of the surfaces. Proper chemical surface preparation, has been found to be of great assistance in lengthening the electrode tip life between dressings, in the case of the more difficult magnesium alloys. The harder surface magnesium alloys do not require a double pressure system in the spot welding machine for the purpose of avoiding cracks, since the weld pressure itself must be sufficiently high to obtain satisfactory contact with the harder surface.

Hardenable Steels.—Electric resistance spot welding has heretofore been limited to steels of extremely low carbon content and hence hardenability, owing to the very brittle structures produced by the rapid cooling rates associated with the spot welding process. Spot weld cooling rates are so severe that the martensitic structure may be produced in 0.040-in. plain carbon steel having only 0.10% carbon. Although the martensitic structures produced by these extremely high cooling rates render spot welds made in the ordinary manner unsatisfactorily brittle, it is a perfectly sound metallurgical principle that the toughest steel structures are produced when martensitic structures are tempered. Experiments with the tempering of spot welds[23,24] showed that fully satisfactory tempering could be accomplished in as short as, or even shorter times, than

were required to make a spot weld in any given gage of steel. In order to produce tough spot welds in hardenable steels, it is only necessary to provide a control circuit which will give not only a timed current for spot welding, but also a time for quenching to martensite followed by a timed current for tempering. When spot welds are stressed at right angles to the sheet surface, a severe notch condition is encountered, due to the spot weld geometry. Owing to this condition, spot welds in low-carbon steel exhibit only from 1/2 to 3/4 of the shear strength, when tested in this direction. Untempered spot welds in hardenable steels, may exhibit only from 5 to 30% of shear strength when tested in this manner. On the other hand, tempered spot welds will again exhibit from 40 to 60% of shear strength when stressed at right angles to the sheet surface. Thus the tempering process makes structures, which would otherwise be entirely unsatisfactory for service applications, entirely satisfactory and practicable. The slightly longer time required by the quenching and tempering operation, may easily be justified by the very great improvement in the resultant quality of the weld. With this process, there appears to be no limit to the hardenability of the material which can satisfactorily be spot welded. In a recent application, a steel containing 0.70% carbon was satisfactorily welded. All of the low alloy and aircraft type medium alloy steels may now be satisfactorily spot welded, if the tempering process is employed. This method is already being applied in production on a number of low alloy high strength structural steels and also on medium carbon steels. Sufficient experimental data has now been obtained to permit the establishment of welding conditions for any steel if the thickness and composition of the steel are specified. This information has recently been gathered to permit easy industrial application of the process.[24] As an example of the effectiveness of this process, even the shear strength in spot welds in 0.040-in. SAE 1045 steel is increased three times by tempering, and the tension strength at right angles to the sheet is increased approximately 10 times by tempering. In the application of this process, tempering alone is sufficient to secure optimum properties in all steels in gages up to 1/8 or 0.125 in. in thickness. For greater thicknesses, additional benefits can be obtained by a grain refinement treatment in addition to the tempering treatment.

Spot Welding of Heavy Gages of Steel.—Although the vast majority of the applications of spot welding to steel have been limited to gages of 1/8 in. or less, some welding in heavier gages up to 3/4 in. has been practiced for a considerable length of time. Much information has been gathered as a result of recent investigations to show the practicability of spot welding steel in gages from 3/16 to 1/2 in. Spot welding in this thickness range can be carried out on machines of only slightly greater capacity than are now very commonly used for spot welding the thinner gages, below 1/8 in. Ordinary spot welding machines of the press type, particularly those developed for projection welding, and capable of delivering from 25,000 to 40,000 amp., are suitable for welding gages of steel within the range from 3/16 to 1/2 in. Although a form of spot welding, known as pulsation welding has been recommended for this thickness range, recent experimental evidence has shown that most if not all of the applications for which projection welding has been recommended, may be carried out using continuous currents either of a single magnitude or in some cases of two magnitudes, the former being used for preheating purposes to insure intimacy of contact before passing the heavy welding current. One of the advantages frequently claimed for pulsation welding is that of longer electrode life, due to the supposed ability of the electrode to be cooled during the time when the current is cut off between successive pulses. It may be shown by experiment that if the same size weld is made in the same total length of time by any of several different pulsation sequences, or by a single continuous impulse of current of the same total duration and the same effective heating value, the average temperature reached by the surface of the electrode is the same. Detailed reports of this and other comparisons between pulsation and single impulse welding will soon be available for publication. In the spot welding of heavier steel plates, difficulty may be encountered in securing sufficient intimacy of contact at the faying surfaces, due to plate distortion. It has frequently been found advantageous in these cases to use a lower magnitude of current for the first part of the single impulse weld in order to somewhat soften the plate and permit the attainment of intimacy of contact before passing the heavier welding current. Although advantages have been claimed for pulsation welding in this respect, experience has shown that the use of a preheat current immediately preceding the welding current, is capable of taking care of this type of problem in a more satisfactory manner. Cleaning of the steel surface from rust or mill scale by grit blasting is usually preferable when spot welding these heavier gages of steel. However, the use of a preheat current of low magnitude preceding the higher welding current, has been shown to be capable of rendering the gray mill scale on hot rolled plates or shapes sufficiently conducting to permit passage of the welding current, and the production of satisfactory welds, with reasonable electrode life. Further experimental tests are needed to determine whether spot welds produced on scaly steel possess mechanical properties which are in every way the equal of spot welds in grit blasted material. Old mill scale, pitted by rust, is a much more serious problem, and in general the spot welding of this type of surface should be avoided. It has been found that electrodes for the spot welding of heavy gages of steel plate should have a dome-shaped contacting surface of relatively large radius, e.g., 8 to 10 in. These dome-shaped electrode contacting surfaces should be restricted in diameter to approximately 10% greater than the diameter of the weld which it is desired to produce. This permits sufficient sinking in of the electrode to avoid porosity and shrinkage cracks within the weld. The diameter of spot welds in the heavier gages of steel should preferably be at least three times the thickness of a single plate, but in no case less than twice the thickness of a single plate, if severe stress concentrations are to be avoided.

Arc Welding of Thin Sheets.—An important new frontier for arc welding has resulted from the development of electrodes satisfactory for spot welding of thin gages of sheet steel.[25] These electrodes permit the arc welding of sheet steel at very high speeds, using electrodes of much larger diameter than was formerly thought possible, the welding being carried out with much less danger of burning through the sheet material or of causing sagging of the underlying sheet. Special methods of testing to determine the suitability of electrodes for this type of application have also been developed.

Arc Welding of Hardenable Steels.—Although it has been known for some time that alloy steels could be welded with reasonable satisfaction, using austenitic electrodes, more recent developments have shown that even greater satisfaction may be obtained with the proper type of ferritic electrodes. Difficulty with earlier electrodes for this type of work lay in the abnormal tendency for weld metal and underbead cracking. The newer electrodes have very much less difficulty from weld metal cracking and are practically entirely free from

underbead cracking. This underbead cracking has been shown to be associated with the use of an electrode coating which tends to introduce large volumes of hydrogen into the arc stream. The newer electrodes utilize a lime-type coating of similar composition to that used on stainless steel electrodes. An advantage of the newer type ferritic electrodes lies in the possibility of developing sufficiently high strength in the weld deposit to match the characteristics of the alloy steel plate. Welds having mechanical properties which are equal or superior to those of the base metal, produce joints which are likely to prove superior to joints made with weaker weld metal. The possibility of avoiding underbead cracking permits the use of values of weld energy input insufficient to avoid the production of a martensitic structure in the zone immediately adjacent to the weld. If cracking is avoided, these martensitic structures may be tempered by the heat of succeeding passes of arc-deposited metal, or by a subsequent furnace treatment.

New Equipment.—Greatly expanded opportunities for the arc welding of heavy steel plates in a single or at most two passes of the welding arc, submerged under a blanket of molten flux, has made possible speeds of welding many times greater than the best speeds obtainable with multipass welding. The availability of submerged melt welding was in no small degree responsible for the enormous production of ships during the recent war. This process continues to provide a new frontier for peacetime application. The inert gas shielded arc, developed for the fusion welding of the readily oxidizable magnesium alloys, has found wide application not only for its originally intended purpose but also for the fusion welding of thin gages of aluminum alloys and of stainless steel. The development of automatic equipment for these and other arc welding processes tends to widen the fields of application.

The problem of providing adequate power supply for electric resistance spot welding machines has always been an important one. This problem becomes more acute when it is desired to provide for the spot welding of high conductivity aluminum alloys. The problem was further accentuated when it was desired to provide for resistance welding in the greatly expanded aircraft industry. This problem was solved by the introduction of stored energy spot welding machines of the electro-magnetic and electro-static types. The stored energy machines are capable of taking energy from all three phases of a polyphase power system, and at substantially unity power factor. Furthermore, the power is taken from the line over a longer period of time and hence with a lower maximum demand. These machines have been improved as to consistency of operation and quality of welds which can be produced. The improvement in quality of the welds has been brought about by the introduction of the double pressure system and by more careful attention to the details of mechanical construction of the welding machine. Improvement in control mechanisms has contributed greatly to improvement in consistency of weld strength. It may now be said with confidence that with existing equipment and methods of quality control, the use of spot welding as a substitute for the riveting of aircraft structures may now be confidently and justifiably applied.

An even newer type of stored energy spot welding machine utilizes the principl of electricale energy storage in batteries. Important developments in electrical contactors to permit the direct switching of extremely heavy spot weld currents, together with improved construction of storage batteries for this application, and methods of control of storage battery voltage, make this type of welding of great practical significance.

The electro-magnetic and electro-static stored energy welding machines are satisfactory for welding moderate gages of the high conductivity aluminum alloys. The enormous increase in the size of condenser installation or reactor required for welding the heavier gages of aluminum alloys, makes these types of installation less practicable from the viewpoints of both cost and size of equipment. For these cases either the storage battery type of equipment or specially designed polyphase alternating current equipment may be preferable. The stored energy machines are also not satisfactory for the spot welding of steels or other higher resistivity materials in the heavier gages. This is due to the inability of the electro-magnetic and electro-static stored energy machines to store sufficient energy and deliver it over a sufficiently long period of time to produce satisfactory welds. For the spot welding of the medium to heavier gages of steels and other metals of equal or higher resistivity, alternating current equipment is preferable. If the single phase load of poor power factor common to ordinary alternating current spot welding equipment is objectionable, either capacitor installations may be employed to improve the power factor, or a polyphase welding system may be utilized.

Looking Ahead Through Research.—Our discussion up to this point has concerned itself with frontiers of more or less immediate application of welding processes. The industry is extremely fortunate in having such a strong arm of research as is represented by the Welding Research Council of which Dr. Adams is Chairman. Through the continued efforts of this organization supported by far-sighted leaders of industry, we may hope to continually open new frontiers of exploration which will inevitably lead to expanding new frontiers of application. Although much has been learned, as indicated above in the fields of welding metallury and residual stresses, much more fruitful work may be expected in both of these fields. Although we have found out a great deal about weld quench effect, there is still much more to be learned about the effect of the time-temperature relationships associated with arc welding, in such matters as precipitation of oxides, nitrides and of carbon and carbides. Although we know a great deal about the magnitude and distribution of residual stresses, much more needs to be known about the significance of these stresses in various types of structures subjected to different kinds of loading.

Although great progress has been made in the field of resistance welding, we may look forward to still further improvements in projection welding, seam welding and flash welding, both as to methods of operation and as to equipment.

In the field of arc welding, we can look forward to much greater improvements in the development of welding electrodes, providing at the same time, better quality of deposited metal and better operating characteristics, in all of the positions of welding.

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The Classification and Recording of Spot-Weld Defects Revealed by Radiography

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Introduction

THE interpretation of radiographs of spot welds in aluminum alloys has been discussed in previous papers.[1, 2, 3] The methods of interpretation have been found to be reasonably valid by several independent investigators[4, 5, 6] and have been appended to specifications for the guidance of aircraft manufacturers.[7] Through their use, radiography has been found to be a useful nondestructive method of spot-weld process control and inspection.

However, the radiograph of a defective spot weld may often be a rather complex image, difficult to describe objectively or quantitatively. The usefulness of spot-weld radiography in process and quality control would be severely limited if its results could not go beyond subjective judgments. The effective procedures of statistical quality control, the equalization of inspection standards in separated plants and the permanent recording of inspection data require a reproducible quantitative measure of the significant spot-weld defects revealed by radiography.

This paper presents a possible method of classifying the presence and extent of spot-weld defects revealed by radiography, by which observations from spot-weld radiographs can be recorded and transmitted from one individual to another. From these tentative classifications, process control engineers and inspectors could establish standards and specifications of acceptance levels for each individual defect or group of defects.

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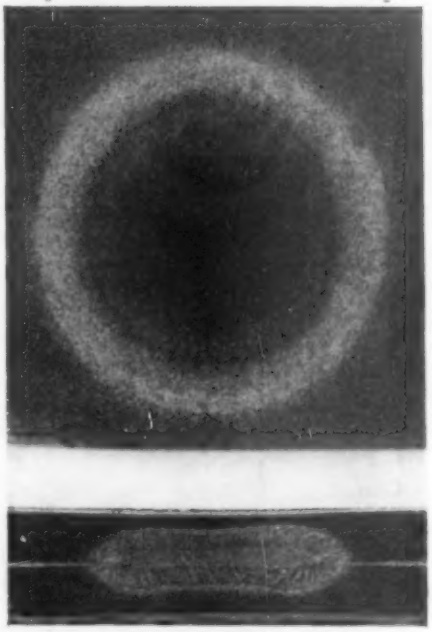
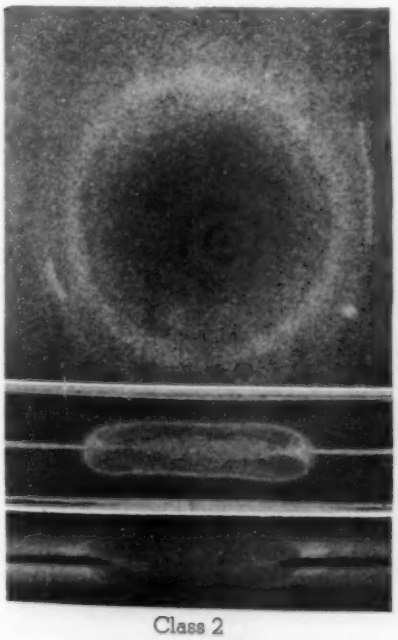
Weld Defect Classification Charts

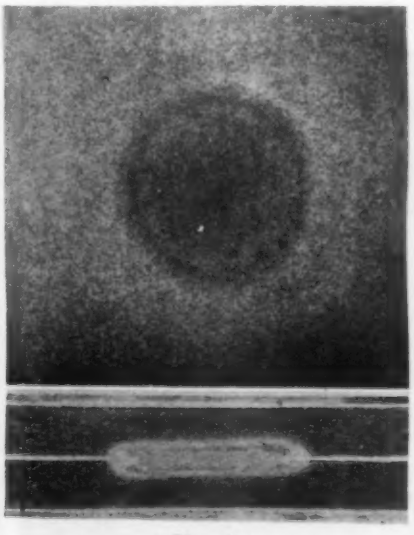
Only those weld properties which determine the strength and physical properties of the spot weld, and those which provide significant information concerning the operation of welding equipment or the control of the spot-welding process, are in-



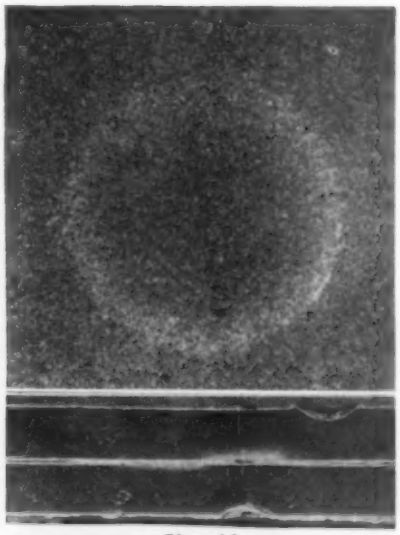
Class 0
Normal Weld



Class 2

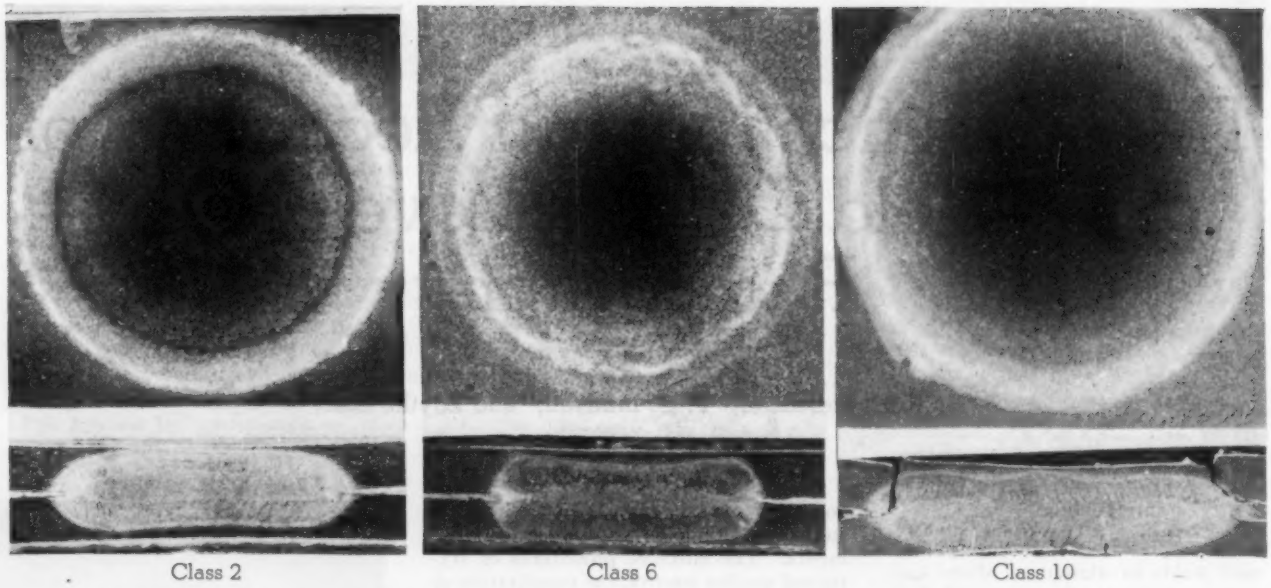


Class 6



Class 10

Chart I—Undersize Spot-Weld Nuggets (All Specimens in 0.040-In. 24ST Alclad. 6.5 ×)



Class 2 Class 6 Class 10

Chart II—Oversize Spot-Weld Nuggets (All Specimens in 0.040-In. 24ST Alclad. 6.5 ×)

cluded in the following tentative classification. Many other details of structure revealed by spot-weld radiographs, which were discussed in previous papers, are not included in this classification because as yet no reliable correlation between these indications and significant weld properties or process variables has been proved to exist.

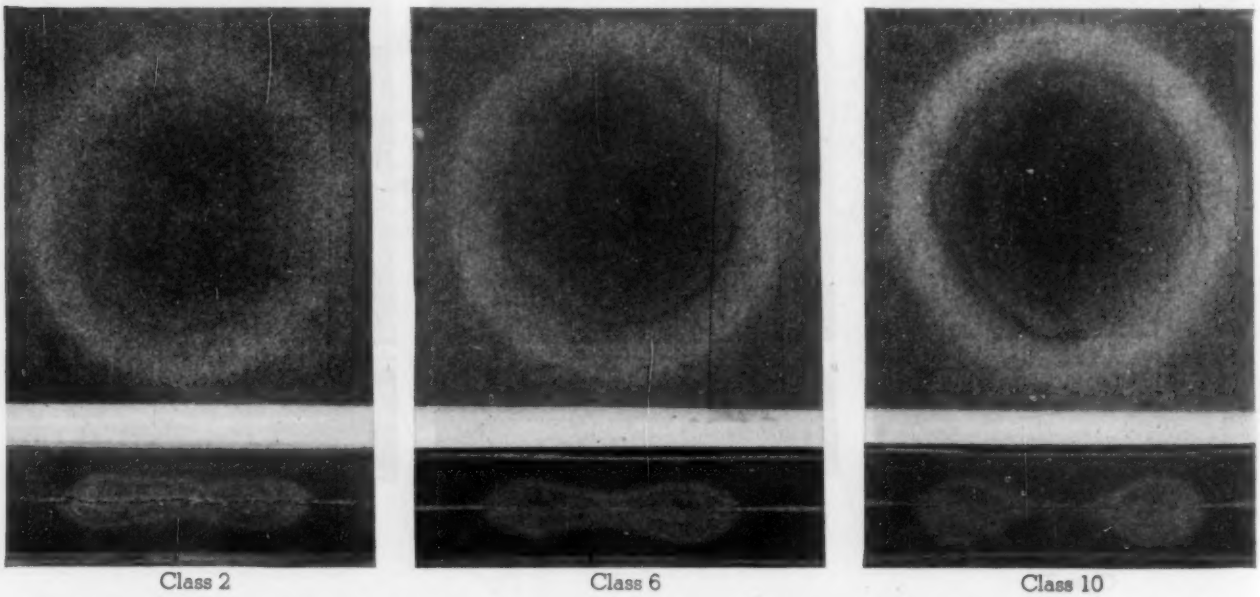
The following weld defects are tentatively classified in the charts on succeeding pages:

Chart I.	Undersize Weld Nuggets (inadequate diameter or penetration).
Chart II.	Oversize Weld Nuggets (large diameter or excessive penetration).
Chart III.	Doughnut- or Crescent-Shaped Weld Nuggets.
Chart IV.	Misshapen Weld Nuggets.
Chart V.	Extent of Alclad Inclusion (into nugget at interface).
Chart VI.	Extrusion of the Weld Nugget (at the faying plane).
Chart VII.	Cracking of the Weld Nugget.
Chart VIII.	Porosity in the Weld Nugget.
Chart IX.	Expulsion ("Spit") at the Faying Plane.
Chart X.	Segregation of Eutectic in the Parent Material.
Chart XI.	Welding Electrode Tip Pickup.

Certain weld properties revealed by radiographs are not included in the classification. These include segregation and differences in structure in the weld nugget, size of the granular zone within the weld nugget, differences in nugget penetration within the acceptable range of 20 to 80% of the sheet thickness, and size and shape.

The tentative classifications of the charts are based upon welds selected from more than 10,000 production spot-weld specimens radiographed and tested during research. More serious defects, or other types of defects, may be found as spot-weld radiography is widely applied in industry. In this case, the charts may be modified or supplemented to increase their range, usefulness and validity.

All of the examples which follow were selected from spot welds in two-layer, equal-thickness combinations of 0.040-in. 24S-T Alclad aluminum alloy, so that ready comparisons can be made between examples. Similar weld properties were found for 24S-T Alclad and 75S-T Alclad aluminum alloys in all gages from 0.016 in. to 0.188 in., and for dissimilar sheet thickness combinations as extreme as 0.040-0.188 in. Nugget diameters and typical defects vary in size in proportion with sheet gage, but the general appearance of the spot-weld radiographs varies little save in size. In the heavier gages, the radio-



Class 2 Class 6 Class 10

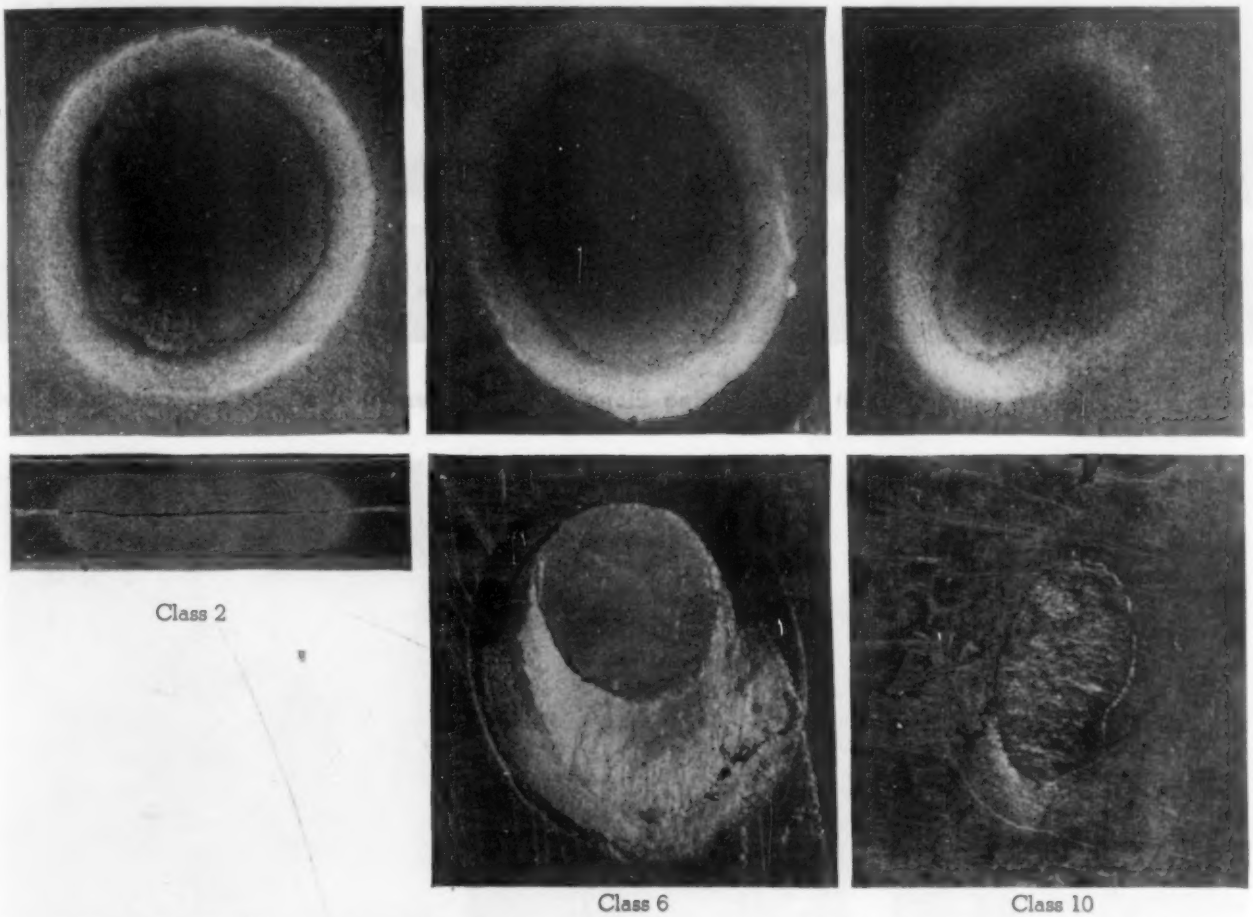
Chart III—Doughnut-Shaped Spot-Weld Nuggets (All Specimens in 0.040-In. 24ST Alclad. 6.5 ×)

graphic definition and contrast sensitivity are improved, so that clearer and more detailed spot-weld images can be obtained.

Each spot-weld defect is classified in the charts by number according to the degree or extent of the defect. Absence of the defect (i.e., a perfect spot weld in so far as the specific defect is concerned) is classified as 0. Successively worse conditions of the defect are classified by increasing numbers from 1 to 10. The number 10 is assigned, in general, to the worst example of the defect observed during the period of the research. The charts include examples of defects classified as 0, 2, 6 and 10. The intermediate classifications are omitted from the charts, but may be used to designate defects which fall between two adjacent classes shown on the charts.

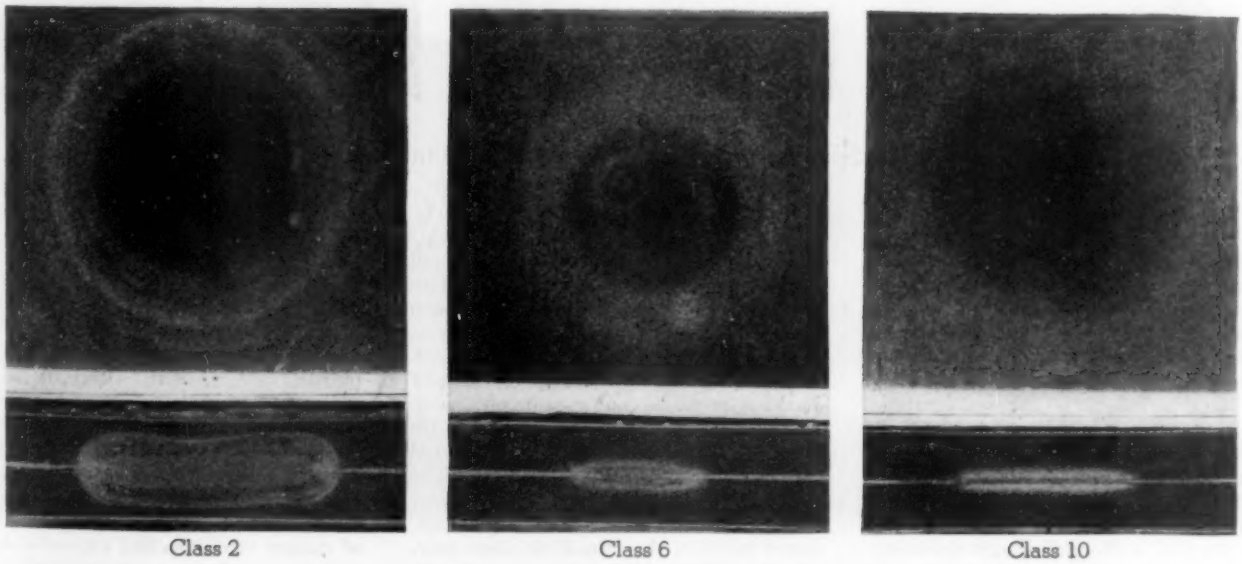
Weld Defects Influencing the Load for Static Shear Failure

Charts I through V classify weld defects



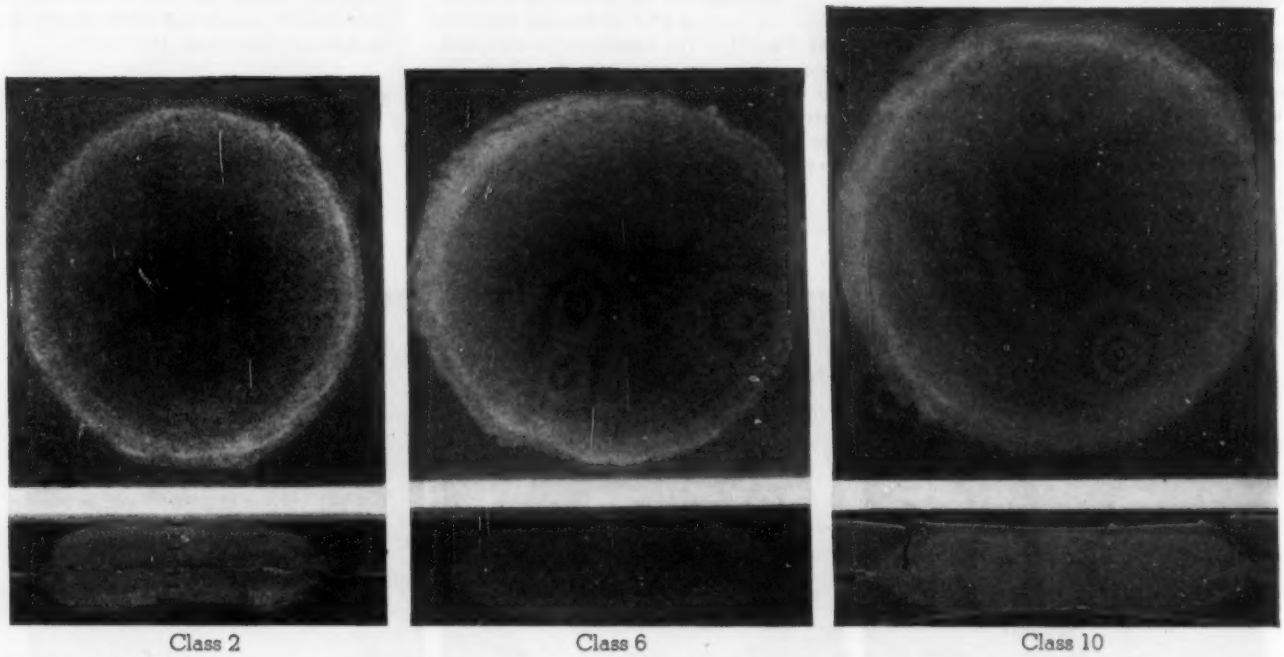
Class 2 Class 6 Class 10

Chart IV—Misshapen Spot-Weld Nuggets (All Specimens in 0.040-In. 24ST Alclad. 6.5 ×)



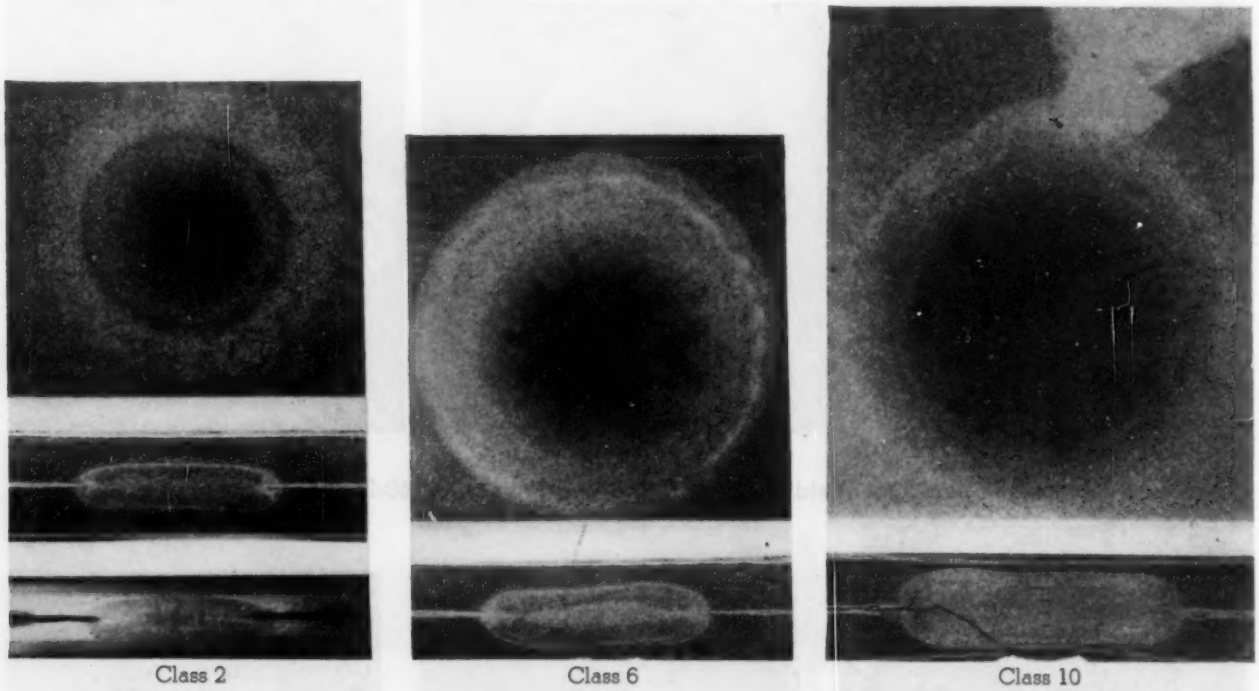
Class 2 Class 6 Class 10

Chart V—Alclad Inclusions at the Faying Plane (All Specimens in 0.040-In. 24ST Alclad. 6.5 ×)



Class 2 Class 6 Class 10

Chart VI—Extrusions of the Nugget at the Faying Plane (All Specimens in 0.040-In. 24ST Alclad. 6.5 ×)

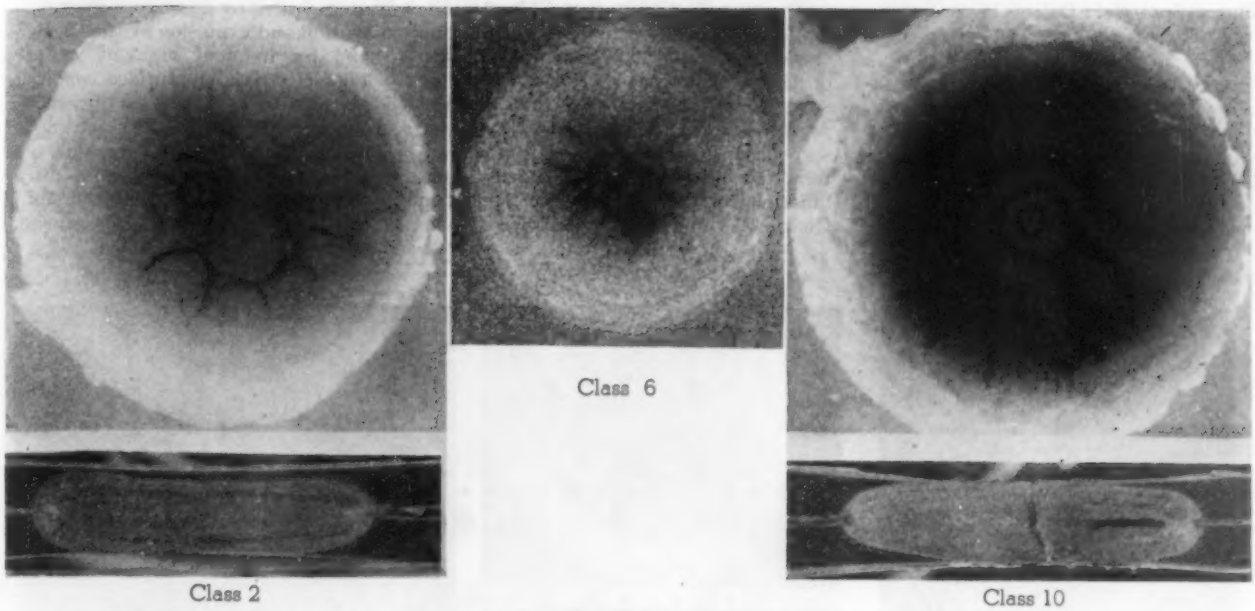


Class 2 Class 6 Class 10

Chart VII—Cracking in the Spot-Weld Nuggets (All Specimens in 0.040-In. 24ST Alclad. 6.5 ×)

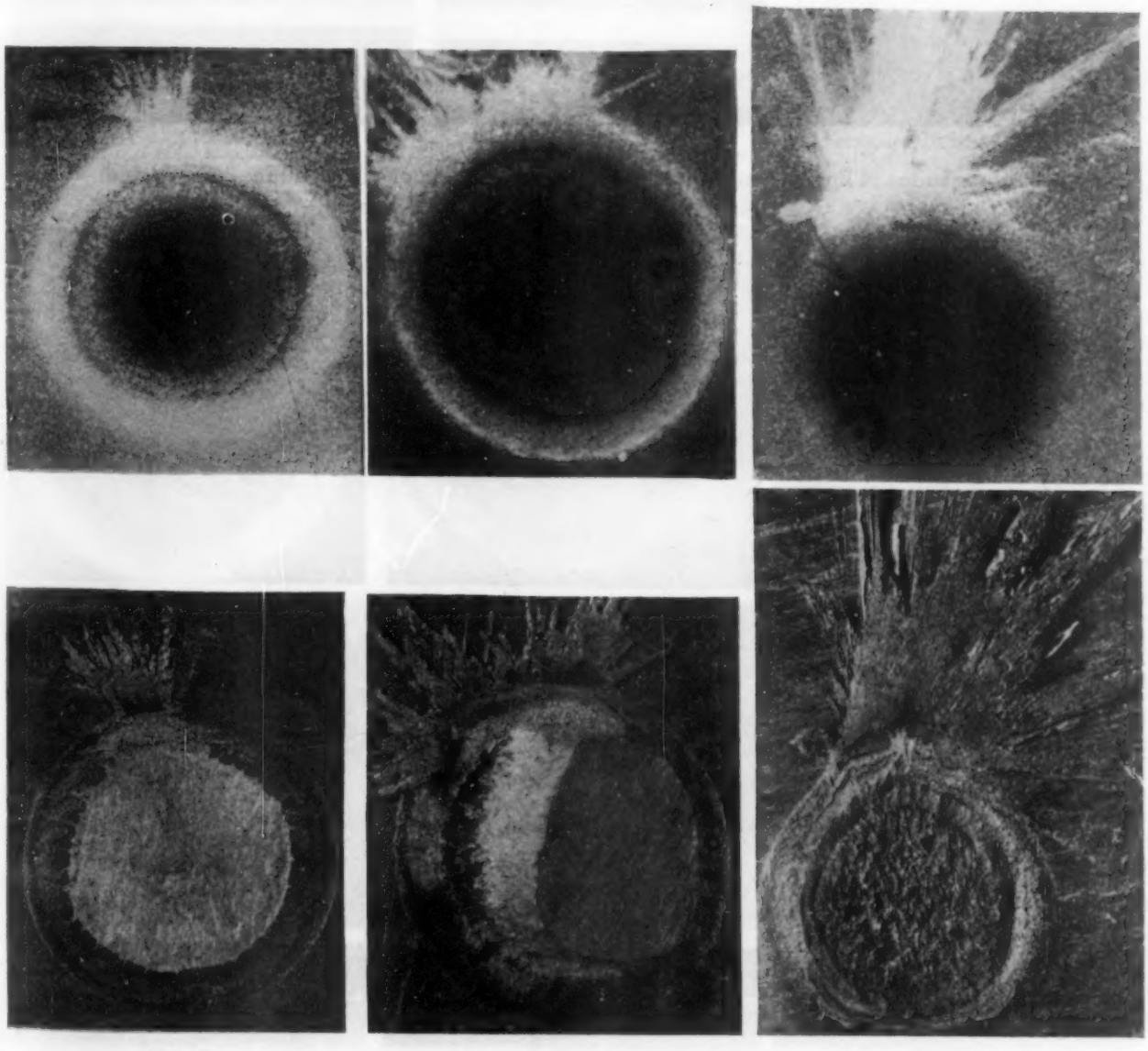
which determine the static shear strength of the spot weld. The classified variables are concerned directly with the reliable measurement of the area of effectively bonded cast alloy nugget material at the faying plane. The net area enclosed by the inner boundary of the radiographic dark ring (or rings in the case of doughnut welds) measures the area of nugget bonding at the interface, and indicates directly the component of weld strength resulting from the existence of the weld nugget.

As the area of the weld nugget decreases in the series of undersize welds of Chart I, the shear strength of the nugget decreases in almost linear proportion. The small nuggets are weak, and below a certain minimum acceptable diameter for each sheet gage, should be rejected. The oversize weld nuggets of Chart II are successively stronger in static shear as the nugget diameter increases, but may be objectionable because of excessive penetration, tip pickup, or other weld defects associated with excessive welding energy. The doughnut welds of Chart III have nugget strengths proportional to the net area enclosed between the two dark rings only, i.e., the effectively bonded area of cast alloy at the faying plane. The misshapen nuggets of Chart IV have strengths proportional to the net area enclosed within the dark ring. The extent and frequency of occurrence of misshapen nuggets are a direct measure of the control of the sheet preparation and of the electrode tip contours and surface condition. Random, irregular variations in weld nugget shape often result from poor, nonuniform sheet surface preparation prior to spot welding. The extent of the Alclad inclusion at the faying plane is a direct measure of the loss of nugget strength, and excessive Alclad inclusions such as are shown in the latter pictures of Chart V are cause for rejection.



Class 2 Class 6 Class 10

Chart VIII—Porosity in the Spot-Weld Nuggets (All Specimens in 0.040-In. 24ST Alclad. 6.5 ×)

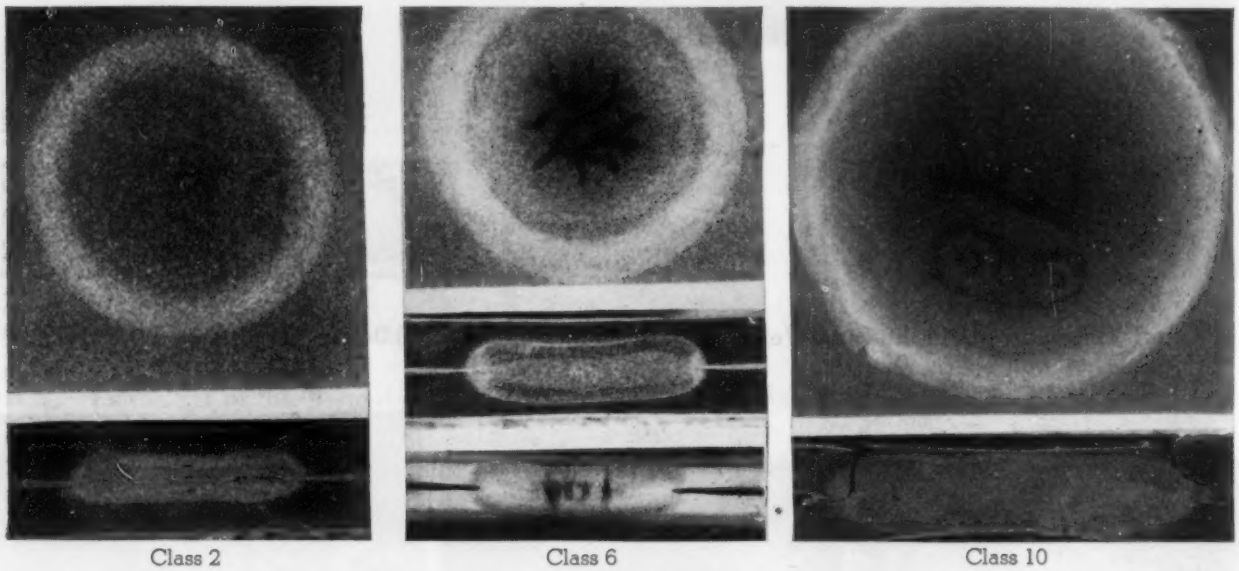


Class 2 Class 6 Class 10

Chart IX—Expulsions ("Spits") at the Faying Plane (All Specimens in 0.040-In. 24ST Alclad. 6.5 ×)

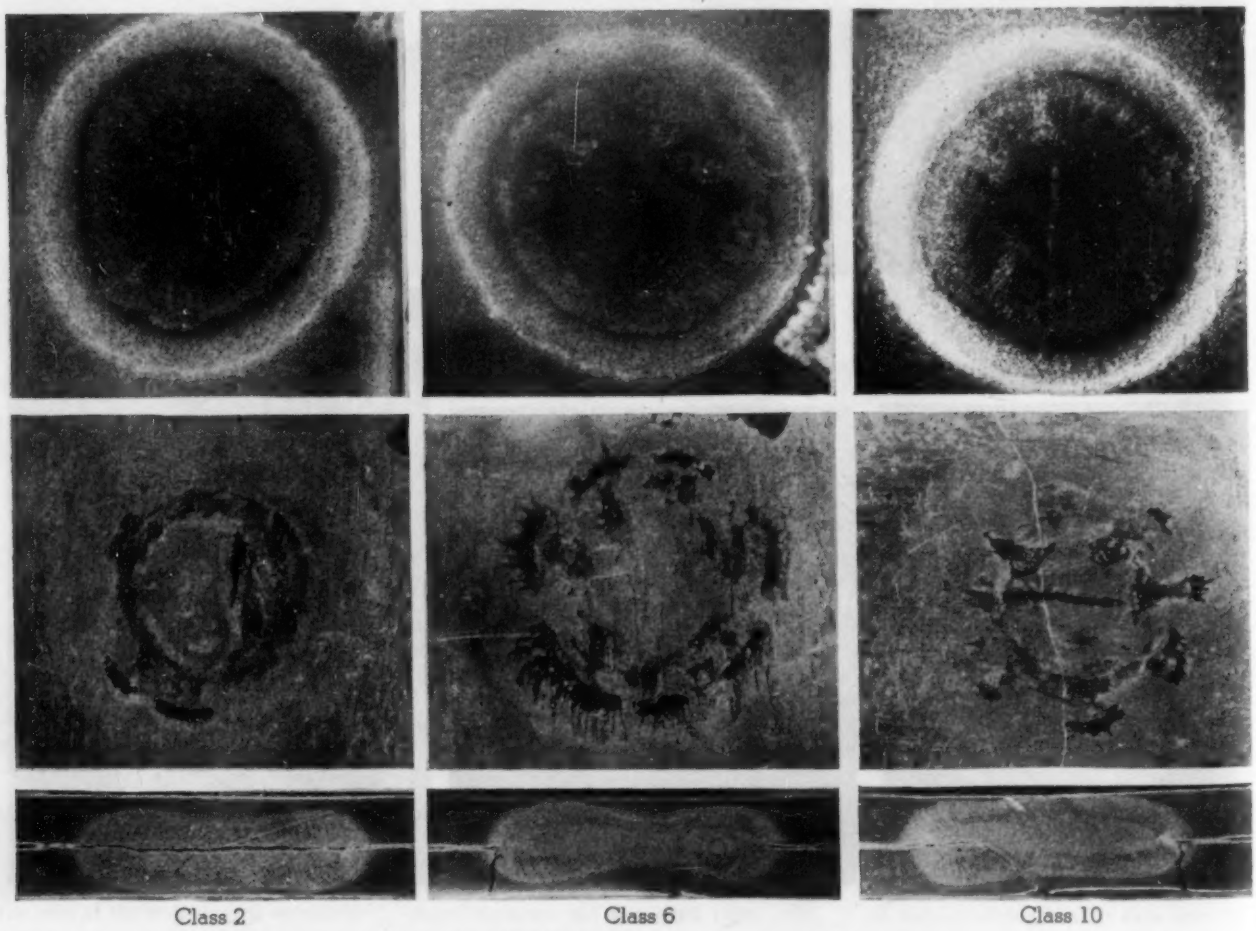
Additional Spot-Weld Defects Important in Process Control

Charts VI through XI are directly concerned with variables which are important in spot-weld process control. These include welding energy and electrode forces during welding and forging, as well as sheet and electrode tip surface conditions which influence the weld energy and pressure distributions. Inadequate tip forces during welding are revealed by cracking, porosity, expulsion and extrusion of the weld nugget. Excessive welding energies for the particular tip radii and pressures in use are revealed by extensive segregation of eutectic in the parent material, by oversize nuggets, and by combinations of the other defects shown in Charts VI through XI. Bad tip contours are revealed by misshapen nuggets, by extrusion and expulsion at the faying plane, and by frequent cracking or porosity. Poor electrode tip surface conditions are revealed by evidences of tip pickup, misshapen weld nuggets and excessive nugget penetration. Nugget cracking, in the absence of other defects listed, often indicates improper forge delay times or inadequate forge pressures. In general, suc-



Class 2 Class 6 Class 10

Chart X—Segregations of Eutectic in the Parent Metal (All Specimens in 0.040-In. 24ST Alclad. 6.5 ×)



Class 2 Class 6 Class 10

Chart XI—Welding Electrode Tip Pickup

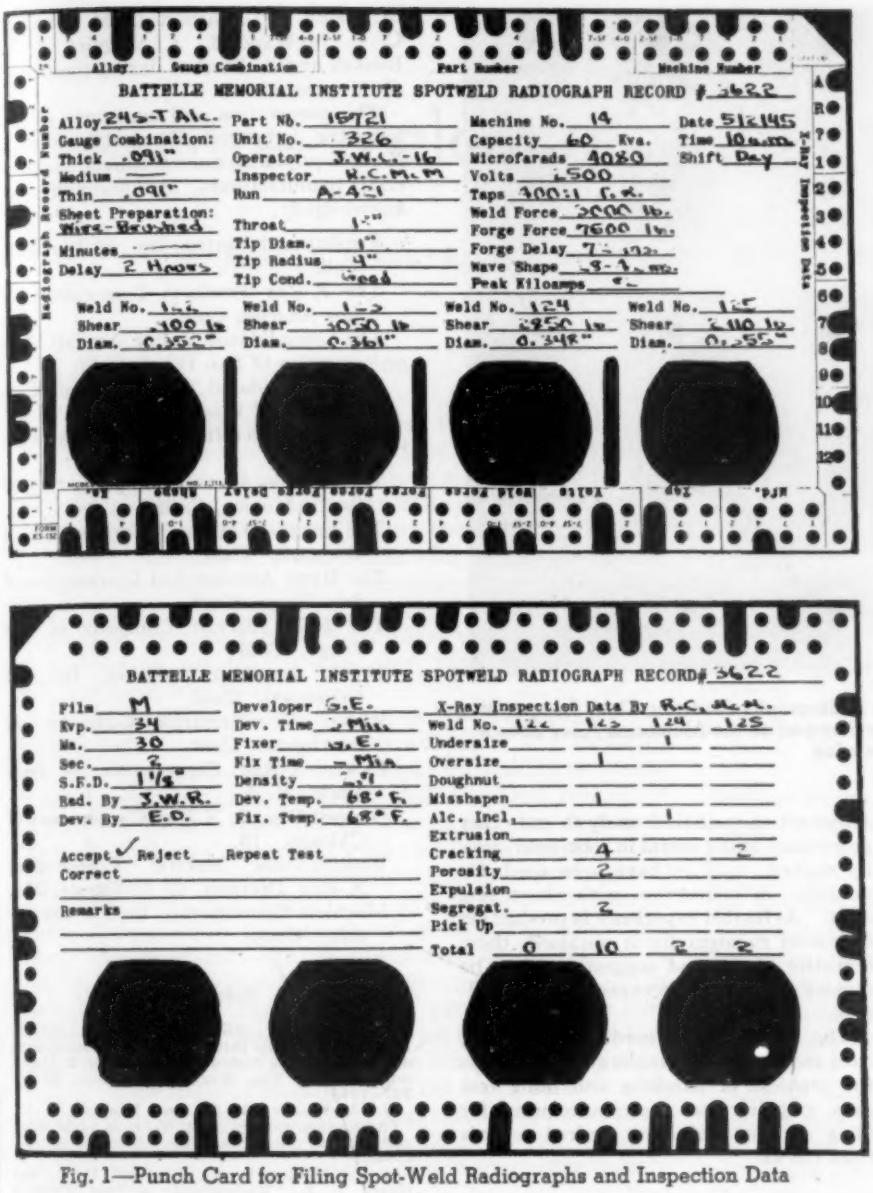


Fig. 1—Punch Card for Filing Spot-Weld Radiographs and Inspection Data

cessively worse degrees of the defects listed in Charts VI through XI indicate progressively wider variations from the normal or optimum operating conditions in the welding variables listed.

Records of radiographic observations can be prepared in simple form with the aid of the charts. Each spot-weld radiograph can be fully described by a series of numbers from 1 to 10, where each number gives an approximate description of each of the eleven types of defects shown by the charts. A limit of acceptability might be established for each type of defect individually, simply by rejecting welds classified higher than a certain number on the chart. Such limits of acceptability might be established at different numerical values for different spot-weld properties, in accordance with their significance. Also, limits might be placed on the total score of a weld for a group of properties, such as those which determine weld strength, so that the combined effects of simultaneous defects might be evaluated. These standards of acceptability might be established either for wide use or for a single department in a factory. In the latter case, the standards might be varied with different parts or products according to the importance of spot welds in those individual parts.

The preservation and filing of large numbers of spot-weld radiographs from production runs and from certification tests can be simplified and controlled with the aid of Keysort or Pathfinder punch cards. The actual radiographic films may be placed in slots over suitable windows punched through the cards, similar to the mounts commercially available for dental films. The radiographs may be viewed readily through the windows, simply by holding the punch card before a suitable high-intensity light source. The cards can be arranged to carry full information concerning the sheet material, the gage combination, the surface preparation, the welding machine number, the operator's identification, the machine settings, the tip conditions, the part and weld numbers, shear test data, and the conditions of the radiographic exposure and the film development. The holes about the periphery of the punch card may be coded and punched to provide the foregoing or other useful information according to which it would be desirable to select, sort or arrange cards. A typical punch card for spot-weld radiographs is shown in Fig. 1. These cards may be sorted readily and rapidly with a sorting needle, as shown in Fig. 2. Any particular radiograph or body of test data can be selected from a large file in far less time with punch cards than with ordinary filing methods.

The Identification of Spot Welds and Corresponding Radiographs

When large numbers of production spot welds are radiographed daily, the identification of spot welds and corresponding radiographs is important. During rush periods, the development and interpretation of spot-weld radiographs may lag several minutes behind exposure, during which period many more exposures are being made. Without positive identification, loss of order during development or other mixups may cause great confusion and, in some cases, delay production or acceptance of parts. However, a convenient and rapid means of positive identification of welds and films has been developed. The sensitivity of spot-weld radiography is so great that numbers rubber-stamped on the spot-welded aluminum alloy sheets with printer's ink (such as Western Electric Co. Vermillion Printer's Ink No. 1318) show clearly on the radiographic film (Fig. 3). These numbers are also reasonably permanent on the aluminum alloy parts, and do no apparent harm to the material.

Concluding Remarks

Radiography of large numbers of production spot welds requires reliable and reproducible reporting of weld qualities from radiographs, as well as effective methods of recording and filing inspection data. The tentative classification charts

Fig. 2—Rapid Sorting of Punch Card Radiographic Record with Sorting Needle

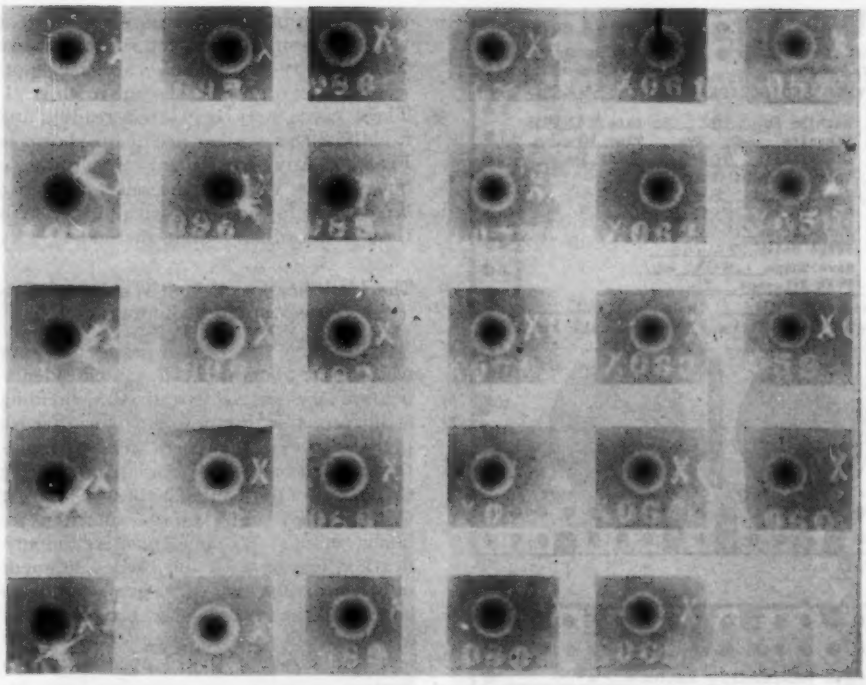


Fig. 3—Contact Reproduction of Spot-Weld Radiographs Showing Clear Images of Identifying Numbers Which Had Been Rubber-Stamped on the Aluminum Alloy Sheets with Printer's Ink

presented in this paper are indicative of a practical method of standardizing the interpretation of spot-weld radiographs. A useful procedure would be the preparation of similar charts from shear test coupons and production parts, in factories in which spot-weld radiography is used extensively in production. The charts could then be designed about the particular materials and sheet thickness combinations in production, and could be arranged to reveal clearly the defects commonly produced by the machines and techniques in use in that factory. The classification and numerical ratings of defects could be made to correlate closely with the particular system of process control and the required spot-weld quality in each application. The particular classification presented in this paper has been used in extensive factory tests in the spot-welding departments of three West Coast aircraft manufacturers, and was found to be a useful guide in training personnel and in maintaining radiographic inspection standards despite changing conditions and personnel.

The numerical classification of significant spot-weld defects makes possible concise recording of information obtained by means of spot-weld radiography. Such numerical inspection data may be used to establish standards, quality ratings and process control records. They may be subjected to statistical analysis and other procedures found useful in spot-weld quality control, such as have been used, for example, in connection with shear test data. As further experience in production spot-weld radiography is obtained, these tentative charts and suggestions may be revised for greater accuracy and usefulness.

The use of punch cards for recording data and filing radiographs greatly reduces the problem of handling and filing test data, and decreases the time required for filing and for obtaining desired records from the file.

Acknowledgments

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The Lockheed Aircraft Corporation, of Burbank, Calif.
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Pressure-Welding Stainless Steel Rings*

By Arnold L. Rustay,‡ Alan Crowell,‡ Stephen M. Jablonski‡ and Charles J. Burch,†

Introduction

THE pressure-welding process was investigated to see whether or not it would be applicable to the production of rings of various sizes for use in the aircraft industry. As the paper will show, welded rings can be produced satisfactorily but the process must be evaluated carefully in comparison with other fabricating methods to choose the most economical method. This paper is a progress report on the application of pressure welding to the production of stainless steel rings ranging in sizes up to 20 in. in diameter with cross sections ranging from $1^1/_2$ to $4^1/_2$ sq. in.

At the time this project was started, several methods of producing the rings were considered. The first method, one that is commonly used, consists of making seamless rings by piercing an appropriate disk and then rolling on a mandrel to the rough dimensions of the part required. This method produces parts with excellent properties but may require considerable manipulation for large rings and is, for the most part, limited to parts of relatively simple cross section such as squares or rectangles. However, these simple shapes can, in a subsequent operation, be die forged to produce fairly complicated contours. The second commonly used method of producing rings consists of upsetting a round or square on flat dies to produce a disk of the desired diameter, then die forging the disk to shape. This method requires that the stock be amenable to upsetting to proper diameter and thickness without excessive cracking. Usually 20 to 60% of the metal is wasted because of the necessity of a large center punch-out.

The third method of producing the rings, used principally for rings of fairly thin cross sections, consists of flash welding appropriately prepared stock to produce the ring. This ring may then be subsequently forged in dies to produce the desired shape. A modification of this process consists of rolling the ring to the desired size and then welding, by means of standard hand methods, to produce a piece which can be forged in dies to the proper shape. Based on our experience, it was evident that the first two methods would produce parts with maximim mechanical properties throughout the ring. The pressure-welding method involves the joining of two semi-circular halves by two diametrically opposite pressure welds. The sequence of steps in making a typical ring is shown in Fig. 1. Our experience with pressure-welding medium alloy steels, such as 4340, had indicated that if the pressure-welding process could be adapted to the manufacture of stainless steel rings it might have production advantages. Induction heating and gas heating are alternate methods that may be used to bring the weld zone to temperature. This paper is confined to a description of the work using the oxyacetylene flame as a source of heat.

A B C

Fig. 1

Sequence of making rings: (*A*) The bent half rings with surfaces prepared for welding. (*B*) Welded ring with the upset bead removed and etched for weld inspection. (*C*) The ring has been die forged to proper size and contour.

One of the prime considerations in choosing pressure welding was the fact that quantities of a given size were not large so that die cost and equipment cost would be an important item in the total production cost of each ring. The other important consideration was that at the time this work was begun, Type 347 stainless steel, containing columbium, was not available because of an expected shortage of columbium, so that Type 321, containing titanium, had to be used. This titanium stainless steel has a greater tendency to crack around the periphery of disk forgings than Type 347. Thus the grinding that would probably be necessary in producing these rings as forgings would have to be weighed against the processing expenses of the welding method. Types and analyses of the steels used are given in Table 1.

Preliminary Work to Establish Welding Technique

At the outset of the program it was decided that the best way to evaluate weld quality for this type of applica-

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‡ Asst. Chief Metallurgist, Development Engineer and Metallurgist, respectively, Wyman-Gordon Co., Worcester 1, Mass.

Table 1—Types and Analysis of Steels Used

Type	C	Mn	Si	Cr	Ni	Ti	Cb
337	0.10 max.	0.04 max.	.....	17.0/19.0	9.0/12.0	....	8 × C
321	0.10 max.	0.04 max.	.....	17.0/19.0	8.0/11.0	4 × C	....
310	0.20 max.	2.00 max.	1.00 max.	24.00/26.00	19.00/22.00	....	....
310 mod.	0.25 max.	2.00 max.	1.75/2.25	24.00/26.00	19.00/22.00	....	....

tion was to forge pressure-welded test sections. Experimental pressure welds were made until the technique was developed to the point where the test welds could be hammer forged without cracking and until the mechanical properties through the welds were satisfactory.

The first test specimens, or 18–8 stainless steel, Type 347, $^{7}/_{8}$ in. thick and 3 in. wide, were pressure-welded and upsets were machined off. They were then forged to reduce the 3-in. dimension to $^{3}/_{4}$ in., a reduction of 4 to 1. The welds had not altered the forgeability of the steel, and the test specimens forged satisfactorily without splitting or rupturing at the weld. The specimens were tested both after welding and after forging. Hot acid etched sections showing the soundness of the weld are shown in Fig. 2. Tensile tests taken through the welds indicated that properties through the best welds were equivalent to those of orginal bar material. Evidence of weld interface was present on the pieces after welding as shown in the photomicrograph of Fig. 3. This interface was not visible on sections taken through welds that had been forged, as shown in the photomicrograph of Fig. 4. Apparently the forging action or the solution treatment during heating for forging has broken up the continuity of the oxide or carbide particles present at the original weld interface.

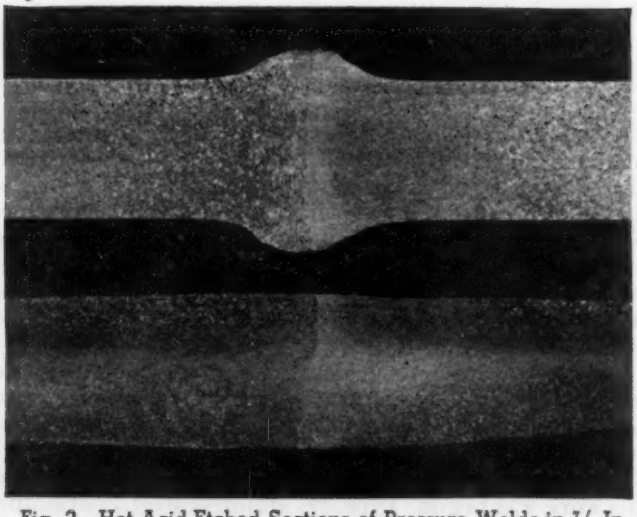

Fig. 2—Hot Acid-Etched Sections of Pressure Welds in $^{7}/_{8}$-In. Sections of Type 347 Stainless Steel; Top Piece Is As-Welded and Bottom Piece Has Been Forged

Pressure welds were next made for forging tests on straight 6-in. lengths in the various section sizes contemplated for rings, as listed in Table 2. The quality of the welds was not consistent, even though the welds had apparently been made in the same manner. Welds made on 1- by 3-in. sections of stainless steel failed at the weld by splitting during forging, as shown in Fig. 5. A more detailed experimental program was then conducted to determine the effects of several variables on the weld quality. The following variables were examined: amount of upset, surface preparation of mating surfaces, temperature, gas flow, heating rate, pressure and time. Type of atmosphere at the weld is another variable that has an effect on the weld.[1] However, at the time this work was carried out, the effect of atmosphere was not investigated. All this work was performed in the atmosphere produced by the heating flames with a 1 to 1 oxygen-to-acetylene ratio.

At the time, it was decided to carry out these more extensive tests using carbon steels for some of the work. However, this program involving carbon steels was soon abandoned as it was found that while carbon steels were

Table 2—Cross-Sectional Dimensions of Rings Produced

Type Stainless	Cross Section, In.
347	$^{9}/_{16} \times 2^{3}/_{4}$
347	$1^{7}/_{8} \times 1^{7}/_{8}$
321	$^{3}/_{4} \times 6$
321	$1^{7}/_{16} \times 2^{5}/_{8}$
310	$^{3}/_{4} \times 2^{1}/_{2}$
310	$1^{1}/_{8} \times 2^{3}/_{16}$
310	$1^{1}/_{8} \times 1^{7}/_{8}$

readily welded within a wide range of conditions, much closer control and more exacting conditions during the weld cycle were required for pressure welding stainless steel. The program was thereafter carried out using stainless steels.

Time, temperature and pressure readings were obtained simultaneously on test pieces, with thermocouple junctions placed on the mating surface at the exact center and immediately below the surface of the cross section, as shown in the diagram of Fig. 6. Hydraulic pressure up to 10,000 psi. was built up at the mating surfaces and the pieces were heated with oxyacetylene torches. Equipment used for this experimental work is pictured in Fig. 7. As the pieces became plastic, they deformed and thus released the pressure across the weld face. Pressure recordings were made simultaneously with time and temperature measurements. Data for one of these sections are plotted in Fig. 8. Tests on this section were repeated with two heating rates, one resulting from 50 psi. of oxygen and the other from 30 psi. of oxygen. From this plot it can be seen that with the faster heating rate resulting with the 50 psi. of oxygen, the temperature gradient across the section was steeper. In order that pressure may be used as a measure of temperature, all pieces of a given cross section must be heated under iden-

Fig. 3—Pressure Weld Made in Type 347 Stainless Steel; Traces of Weld Interface Are Visible Passing Vertically Through the Photomicrograph. × 100

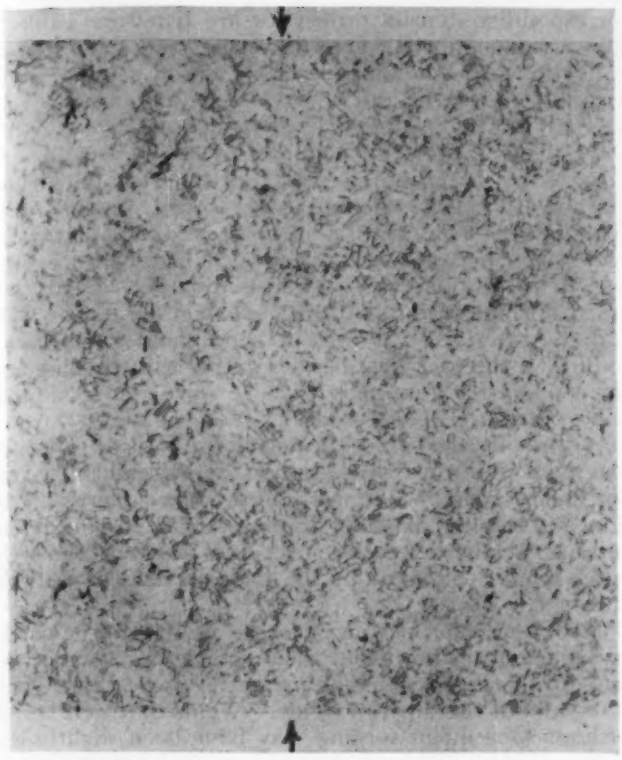

Fig. 4—Weld Made in Type 347 Stainless Steel After Forging and Solution Treatment; The Weld Is Vertically Through the Center of the Photomicrograph. × 100

tical conditions. The most reliable method of doing this was to set up pressure-temperature relationships during the actual welding of these rings.

Temperature and amount of upset were found to be the most important variables in producing a good weld.[2] The importance of temperature has been brought out by other investigators. Welds made at too low a temperature were not bonded. Welds made at too high a temperature had either intergranular carbide precipitation or grain boundary oxidation. The effect of welding temperature on mechanical properties when other variables are held constant is shown in the tensile properties of welds made at various temperatures shown in Table 3. The most satisfactory minimum welding temperature for stainless steel was 2200° F. for a given upset. Welding pressures vary from 3000 to 6000 psi., although varying pressure within these limits had little effect when the temperature was correct.

For welding test pieces, flatness and cleanliness were the most important surface preparations. Satisfactory welds were made with surfaces that had been machine ground, or smooth milled. The amount of upset at the weld was controlled by the degree of total shortening on the test piece and it was found that total shortenings, equivalent to five-eighths of the thickness, were sufficient, provided that the weld faces remained closed during the welding cycle. Although the larger sections had been ground sufficiently flat and smooth for intimate contact at the weld faces, thermal expansion during the heating cycle had caused the outer edges of the cross section to open up before the metal had attained the plastic state. This resulted in oxidation, which prevented proper bonding where the faces had opened.

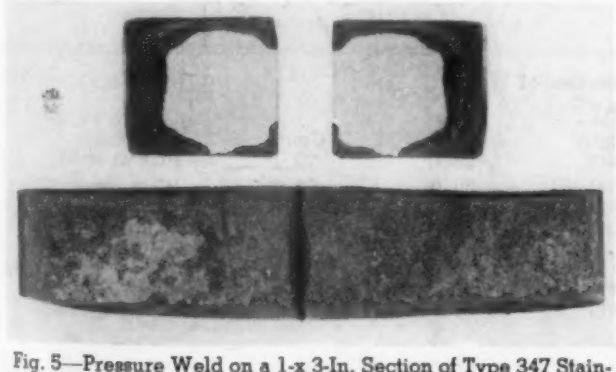

Fig. 5—Pressure Weld on a 1-x 3-In. Section of Type 347 Stainless Steel Failed on Forging; Top Piece Has Been Broken Open to Show the Extent of the Surface Cracking

Tests to Determine Weld Quality

The joint efficiencies of the welds were tested by every available means. Ability to meet the requirements of the forging test was arbitrarily taken as the standard of quality required of pressure welds for these applications. Most drastic and most informative was the forging or expanding test. Other tests were made across specimen welds in order that the results of this forging test could be interpreted in more familiar terms. These included hot acid etch, tensile, Strauss-embrittlement-and-bend and microstructure. The hot acid etch test was useful in exposing cracks in welds not completely bonded to

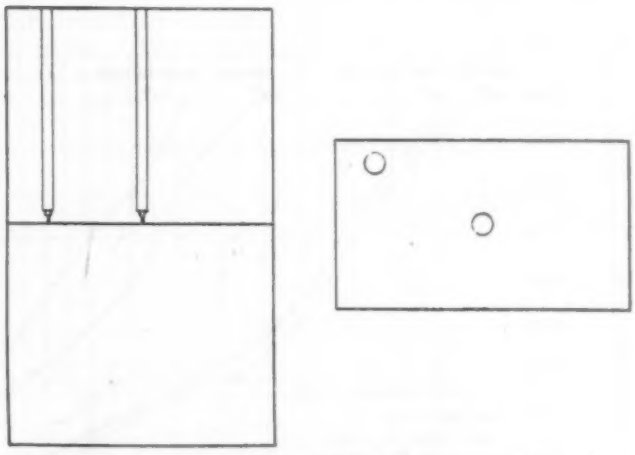

Fig. 6—Diagram Showing Location of Thermocouples on Test Pieces Used for Time, Temperature and Pressure Data

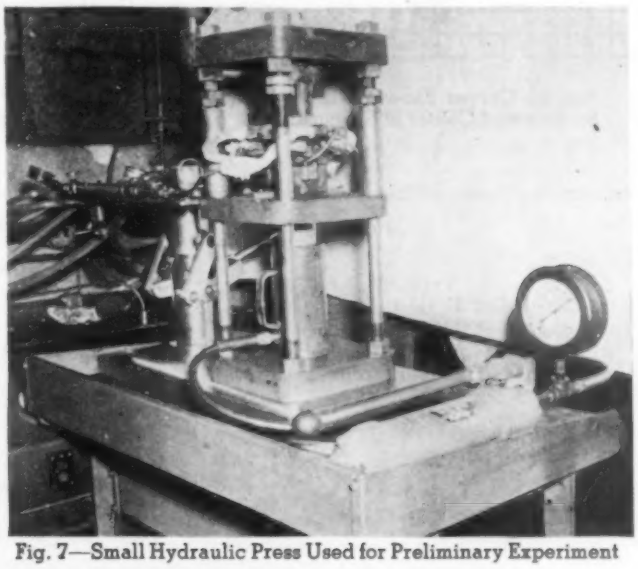

Fig. 7—Small Hydraulic Press Used for Preliminary Experiment

the outer surfaces, and localized burning resulting at the weld from excessive surface temperature. When the bond was poor, the etch disclosed a fine line at the weld, while if localized burning had occurred a characteristic pattern became evident.

When specimens containing defects were forged, they failed in a manner characteristic of the defect. Overheating caused an irregular and intergranular type of failure, while a poor bond caused a flat or straight type of failure similar to that shown in Fig. 5. Tensile tests afforded three criteria for determining weld quality.

1. Ultimate strength.
2. Elongation and reduction of area.
3. Type and location of fracture.

Welds with satisfactory yield and tensile strengths only were readily produced, but more exacting conditions were required in making pressure welds which also possessed optimum ductility. Type and location of fracture on a tensile test were correlated with the strength and ductility. Tensiles that parted exactly at the weld with a flat, dull matte fracture invariably were associated with low ductility, and in some instances low tensile strength. Normal tensile fracture for these stainless steels is a cup-cone type, and welds showing this type of fracture always possessed superior properties of both strength and ductility regardless of whether tensile failure was at or near the weld. Figure 9 shows two tensile fractures. The corresponding tensile properties are listed in Table 3. The Strauss-embrittlement-and-bend tests gave a good indication of weld quality since only good pressure welds were able to withstand the tests. A number of these Strauss tests made on pressure welds are shown in Fig. 10. Only welds appearing sound with a hot acid etch, with satisfactory strength, ductility, and able to fulfill the requirements of the Strauss test, forged satisfactorily. Welds that forged satisfactorily showed complete grain coalescence across the weld, and the interface was well broken up, in some cases entirely eliminated. Welds that failed during forging had not coalesced across the weld and the interface was present throughout. This work confirmed the fact that besides acting as a shaping and sizing operation, forging would also serve as a good proof test of pressure-welded rings.

It was observed that the tensile properties of forged test welds were always better than those of welds that had not been forged. Hot working produced recrystallization, and resulted in a finer grain size. The forging action had also straightened the grain flow fibers at the weld upset, and helped break up the oxide particles at the weld interface.

The superior properties of forged welds may be partly explained on the basis that the severe deformation occurring during forging acted as a selective process that eliminated all but the superior welds. Welds that were tested without subsequent forging may have been slightly less

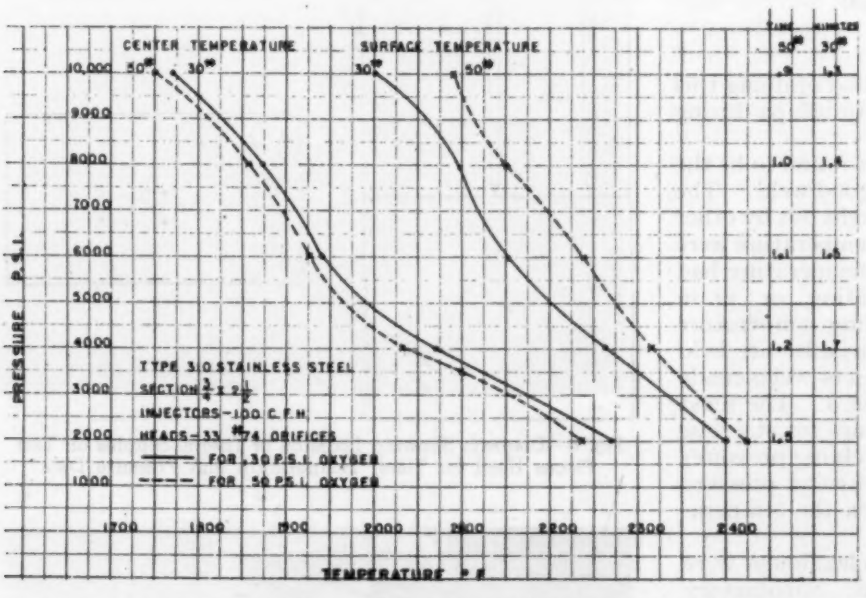

Fig. 8—Curves Showing Time, Temperature and Pressure Relationship for Both Surface and Center of Specimen with Heating Rates Resulting from 50 and 30 Psi. of Oxygen

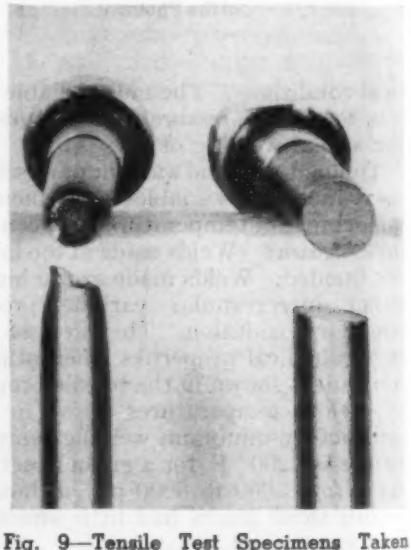

Fig. 9—Tensile Test Specimens Taken Through Pressure Welds

At left, tensile fracture with good reduction of area. At right, flat fracture with little reduction of area, which parted exactly at the weld joint.

Table 3—Tensile Properties of Welds

	Ultimate Strength	Yield Strength	Elong.	Contr.	Fracture
Type 347					
Welded at 2100° F.	77,000	46,500	28.0	29.1	Flat at weld
Welded at 2200° F.	77,000	44,000	39.0	61.0	Cup cone
Welded at 2200° F. and forged	88,000	51,000	55.0	68.5	Cup cone
Unwelded control specimen	88,500	48,500	57.0	59.2	Cup cone
Type 321					
Through weld	78,000	45,000	40.5	44.8	
Original bar	83,000	46,000	61.5	75.1	
Type 310					
Through weld	75,000	40,000	46.0	51.9	
Original bar	75,000	42,000	51.0	50.2	

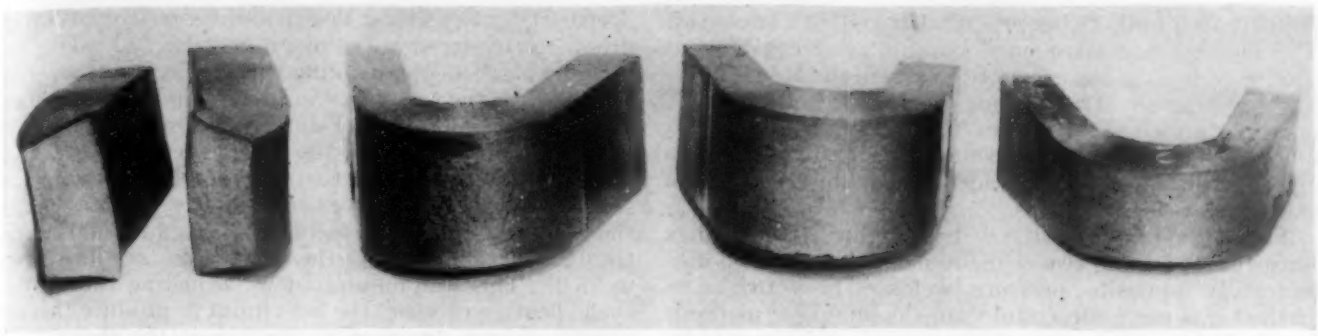

Fig. 10—Strauss-Embrittlement-and-Bend Tests Made Through Pressure Welds in Stainless Steel

Broken specimen at left indicates a failed test piece. All others bent the required 180°. A bend test failure like Specimen A probably would also have a flat tensile fracture.

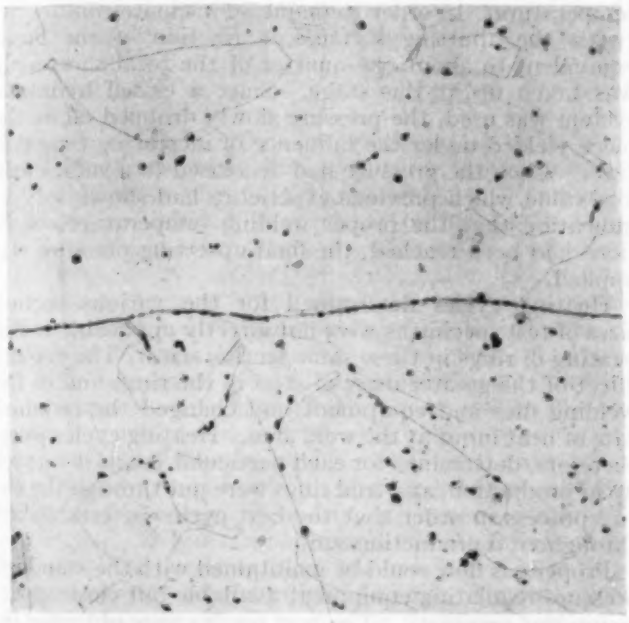

Fig. 11—Photomicrograph of a Pressure Weld in Type 321 Stainless Steel Showing the Presence of Deposited Oxides at the Weld Interface; This Section Had Been Solution Treated and Oxides Remained at the Interface. × 100

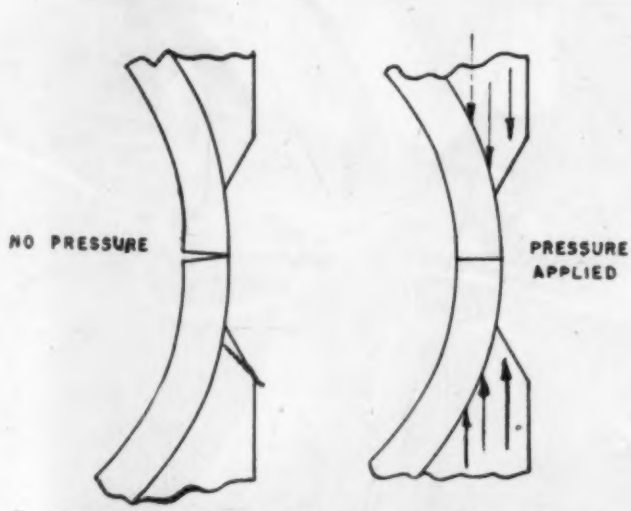

Fig. 12—Faces to Be Welded Were Ground as Shown at the Left; When Pressure Was Applied to the Rings, the Side Thrust Caused the Surfaces to Assume Intimate Contact

perfect, on the average, than forged welds in spite of the fact that all of the other tests such as acid etching indicated equivalent soundness prior to forging.

Although the physical properties of forged welds were superior, the properties across properly welded pieces, not forged, were adequate for the use for which they were intended. Since a number of rings required a rectangular cross section, these rings were made by pressure welding with no subsequent forging. A proof test devised for these welds consisted of expanding, at forging temperature, rings that had been welded $^1/_4$ in. undersize on the diameter. The reliability of this proof test will be discussed later in the paper.

Details of Manufacture of Rings

The first rings were made by welding rectangular sections that had been rolled to a circular form on a three-

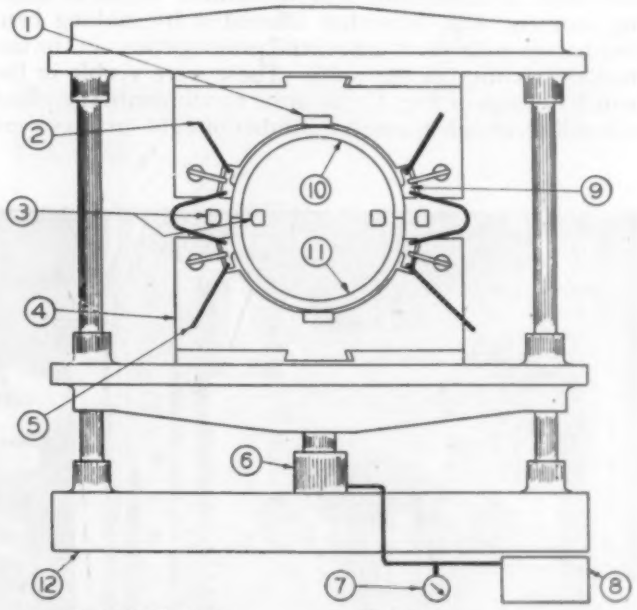

Fig. 13—Schematic Diagram of Pressure-Welding Equipment

point rolling mill. This produced parts with one weld. The method was abandoned because of difficulties encountered both in the preparation and in the actual welding procedure. The mating surfaces could not be properly prepared to obtain the intimate contact required. The bending moment or resultant tended to open up the faces to be welded, and allowed excessive oxidation at these surfaces.

The method finally arrived at in producing these rings consisted of joining two semicircular halves by two diametrically opposite pressure welds. This two-piece method was more successful than the one-piece method. It afforded relative ease in the preparation of pieces to be welded in that the weld faces were readily surface ground and cleaned. The sequence of operations for making rings by this method has already been shown.

Although text pieces were readily welded, numerous difficulties arose in the pressure welding of actual rings. The principal difficulty was the maintenance of intimate contact between the abutting surfaces during the first stage of heating. The metal expanded differentially, because of temperature gradient, so that certain areas of the abutting surfaces separated. This was aggravated by the fact that at no time was the applied load normal to the surfaces. The slight side thrust created was enough to cause considerable trouble. An example of this is shown in the photomicrographs of Fig. 11. Here a heavy oxide film is present at the interface and has prevented coalescence of grains across the joint. However, a film at the weld interface did not necessarily indicate the presence of oxides, as both oxides and carbides were found in this film. Sections through welds containing a film at the interface were solution treated at temperatures up to 2100° F. Carbides present in this film were dissolved into the matrix by this treatment, and the portion of the film remaining after a 2100° F. solution treatment was believed to be composed of oxides. Various fluxes and coatings were tried in an attempt to chemically change this film to volatile products. These were unsuccessful and in most cases deterimental to weld quality. Shields and gaskets were placed around the weld, but were not successful in eliminating film formation. Effect of bending moment was somewhat alleviated by making bent ring halves with short tangential prolongations in the immediate vicinity of the weld. These were visible in the bent half rings of Fig. 1. In order to eliminate the effect of bending, or side thrust, a number of weld surfaces were prepared by a method designated as a "compensating grind," as depicted in the diagram of Fig. 12. This was done by elastically expanding the ring halves to oversize diameters at the weld faces and then grinding. When the proper initial end pressure was applied to these rings, the bending moment caused the weld faces to attain intimate contact. Unequal thermal expansion of the cross section during heating was particularly troublesome on the rings of larger cross section. This expansion caused the faces to open up at the surfaces of sections being welded. This was minimized by adjusting the heating cycle, heating rate and the heat input to produce thermal expansion in a direction to counteract the thermal expansion.

It is almost axiomatic that the higher the end pressure, the lower the temperature at which the metal will undergo plastic deformation. Use of this relationship was made in the welding cycle in that initial end pressure used was high enough to yield plastic deformation at temperatures between 1300 and 1400° F., in order to close any minute opening that may have occurred during heating to this temperature. In order to maintain intimate contact between the abutting surfaces, a fraction of the upset equivalent to about one-quarter of the total shortening was taken up at this stage. Since a closed hydraulic system was used, the pressure slowly dropped off as the piece yielded under the influence of increasing temperature. When the pressure had decreased to a sufficiently low value which previous experience had shown was an indication that the proper welding temperature conditions had been reached, the final upsetting pressure was applied.

Heating cycles determined for the various section sizes of test specimens were not directly applicable to the heating of rings in these same section sizes. The cooling effect of the greater mass of steel in the rings and of the welding dies and equipment had changed the required rate of heat input at the weld area. Heating cycles were, therefore, determined for each particular job as it was set up in production, and trial rings were put through the entire process in order that the best cycles be established throughout a production run.

Proper gas flow could be maintained with the standard pressure-regulating equipment available but close supervision was necessary. The best results were obtained by attaching gas pressure gages to the blowpipe and with the blowpipe needle valves in the wide open position the

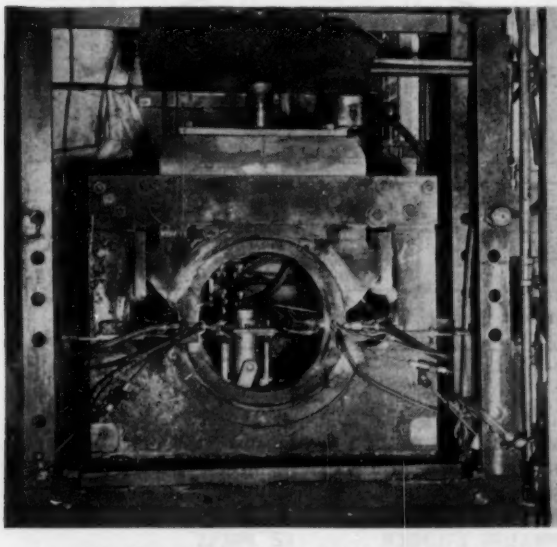

Fig. 14—Pressure-Welding Equipment Set Up with a Ring 16¾ In. O.D. and 13⅝ In. I.D.

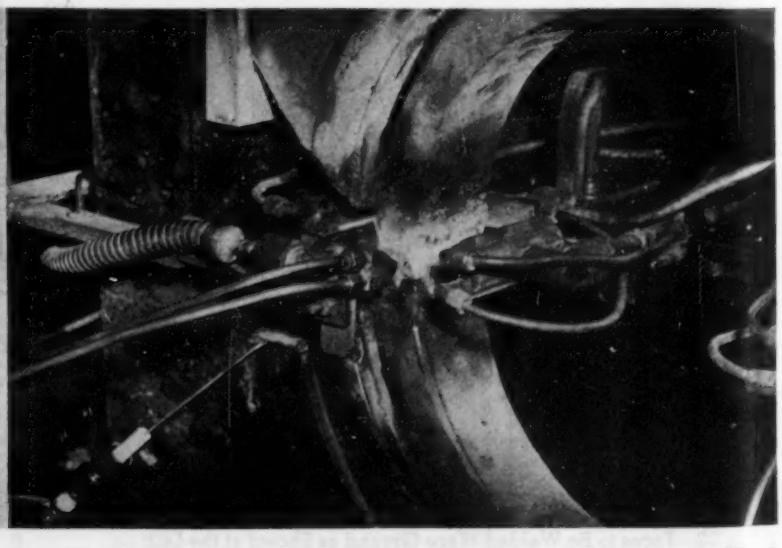

Fig. 15—Close-up of Fig. 14 Showing the Heating Head Arrangement About the Work

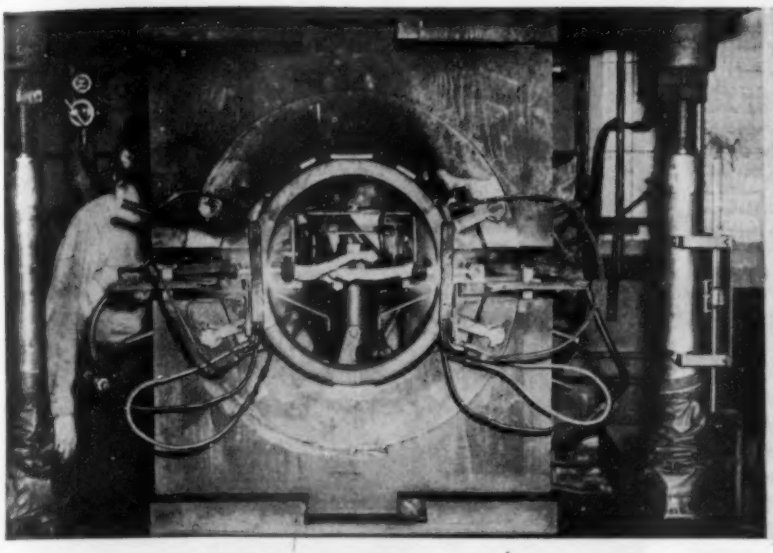

Fig. 16—Larger Size Pressure-Welding Equipment Set Up with a Ring of 19¼ In. O.D. and 16¼ In. I.D.

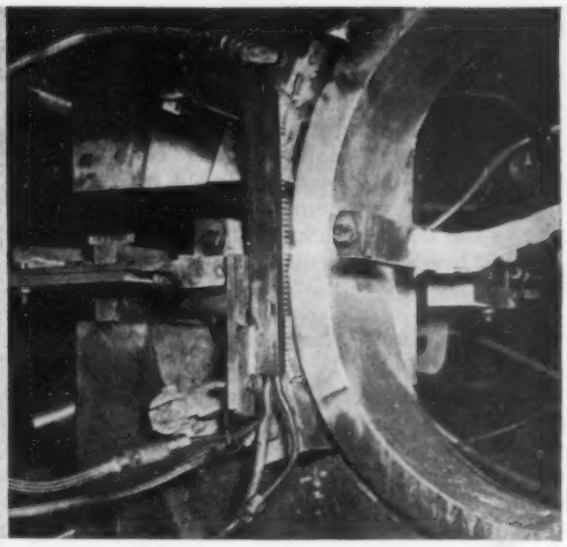

Fig. 17—Close-up of Fig. 16 Showing Heating Head Arrangement and Illustrating the Use of Adjustable Contacts Shown in the Diagram of Fig. 13

injector acted as a critical orifice flowmeter. Delivery pressure regulators in the main gas line were adjusted to maintain line pressures slightly above working pressures, and station regulators were placed as close to the blowpipe as possible to maintain proper working pressure at the blowpipe. With this type of regulation fluctuations in working pressure were minimized, and drops in line pressure did not affect gas flow unless main line pressure dropped below working pressure. The effect of a larger gas flow was an increase in the temperature gradient across the section to be welded as shown in Fig. 8. The gas flow was adjusted to produce a cycle fast enough to rapidly attain plastic deformation and seal the weld faces, but slow enough to minimize the temperature gradient and to provide reasonable assurance against burning at the surface. It was not necessary to know the exact gas flow, provided a constant flow was maintained in order to effect reproducibility from weld to weld. However, lack of adequately sensitive measuring equipment made it difficult to duplicate conditions from one run to another exactly, and close supervisory control was necessary.

Requirements of Heating Equipment

An adequate supply of gases was available from the shop pipe lines. Oxygen supply to the lines was from a large storage unit, and generators provided the acetylene.

The main design consideration of heating heads was that of proper heat input across the section to be welded. In some cases heat input was purposely made uneven in order to counteract the effect of unequal thermal expansion. Heating heads were designed to prevent burning, particularly at the corners of the section, and were mounted to permit easy removal of the rings after welding.

Press Equipment

Presses required sufficient platen area to hold the work and with sufficient strength to exert the proper force. Hydraulic pressure systems were installed on the presses so that variable pressures could be readily attained. Presses were made with sufficient rigidity to maintain correct match of half rings, and with positive stops to insure dimensional accuracy of the welded rings. Dies were required to hold alignment, to support the work and to transfer pressure to the weld. These had to be heat resistant and in the case of larger rings, water cooled to prevent die growth. The portions of these dies adjacent to the work were heated to a dull red when not water cooled. Since they were under pressure, upsetting of the metal took place at these locations and caused the dies to be enlarged at these locations. Some of the larger rings required that die holders be provided with a three-point contact and with adjustable contacts adjacent to the welds. Three-point contacts were required as the hot-rolled surfaces of the bent half rings did not afford proper bearing against the smooth machined surfaces of the die inserts. Adjustable contacts afforded the adjustment necessary to close-mating surfaces and produced intimate contact within the range of tolerances for bent ring

Fig. 18—Crack at the Surface of a Poor Weld in Type 321 Stainless Steel Before Forging. × 100

halves. Heating torches were oscillated across the weld to prevent localized burning. In general the amount of oscillation was equivalent to the total shortening. Both mechanical and manual means were used to obtain this oscillation. A diagram illustrating equipment for pressure-welding rings is shown in Fig. 13. The smaller of the two machines is shown in Fig. 14 with a close-up of the heating head arrangement shown in Fig. 15. Figure 16 shows the larger machine and Fig. 17 a close-up of the heating head arrangement for this machine.

Defects Observed on Welded Rings

Several difficulties were encountered in the early stages of welding of rings. Fissures at the surface of the weld, such as shown in Fig. 18, resulted when the weld faces had opened during the welding cycle. These defects rarely occurred at the inner diameter, but when they did occur they were attributed to too low an initial end pressure. At the outer diameter they resulted from opening caused by excessive bending moment and were prevented by use of a "compensating grind." On the larger cross sections these were due to excessive die growth and were eliminated by the addition of adjustable contacts to the die inserts. The appearance and effect of an oxide film, similar to that shown in Fig. 11, has previously been mentioned. This film resulted when weld faces were not in intimate contact throughout the welding process. This intimate contact was maintained by a number of methods. The "compensating grind" and heat distributions to counteract unequal thermal expansion have previously been mentioned. In some cases sufficient upset was used to force any opened surfaces beyond the contour of the rings. In all cases high initial end pressure and take-up of a fraction of the total shortening under this high pressure helped correct this condition. Burning resulted from too rapid a heating rate in that the surface burned before the center had attained proper welding temperature. Metal that had been burned broke open during upsetting or subsequent forging operations. It was found that Type 310 stainless steels were most susceptible to burning and that this condition could be corrected by proper regulation of heating rate. Low ductility on a tensile test, mentioned previously resulted from a moderate amount of oxides at the interface or too low a welding temperature, and was corrected according to the cause.

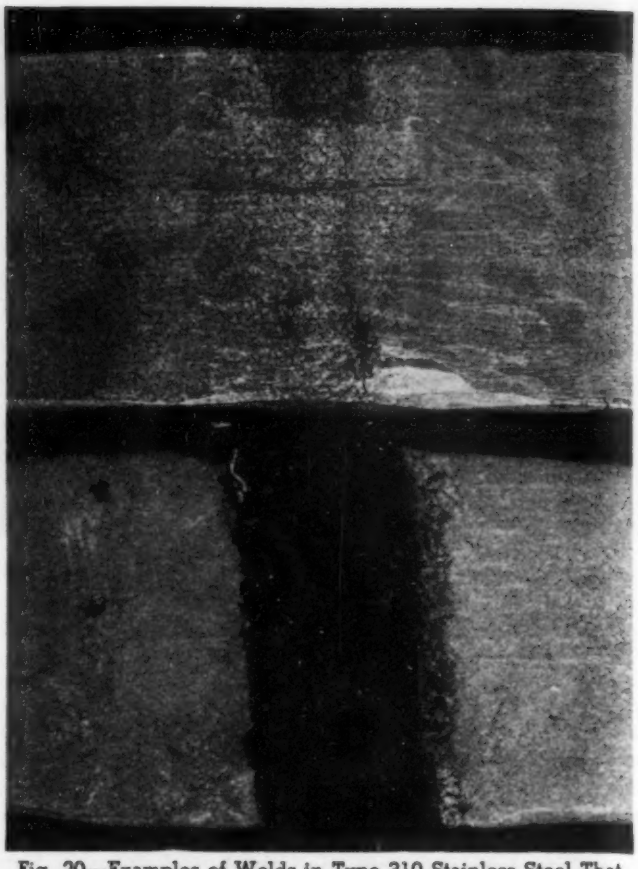

Fig. 20—Examples of Welds in Type 310 Stainless Steel That Have Been Burnt in Pressure-Welding Operation; Top Piece Has Been Welded, Then Etched in 50% Hot Hydrochloric Acid; Bottom Weld Has Undergone the Expanding Test. This Shows the Typical Granular Fracture of a Burnt Weld After Expanding

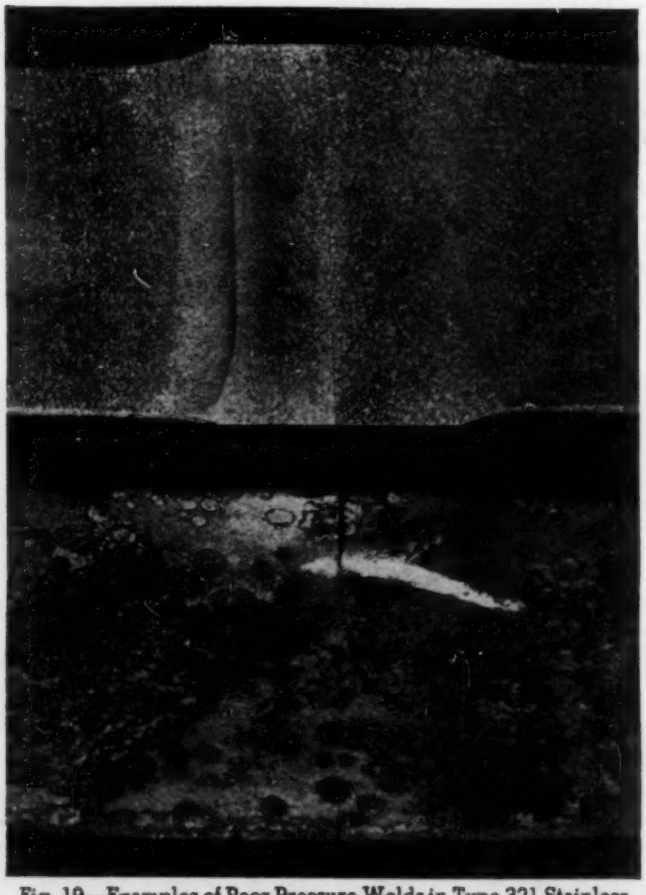

Fig. 19—Examples of Poor Pressure Welds in Type 321 Stainless Steel Rings; Top Piece Is As-Welded with Weld Upset Removed and Bottom Piece Has Undergone the Expanding Test; Improperly Bonded Areas of the Weld Have Split Open

Quality Control

To insure uniform quality of product, a system of quality control was set up. The steels used for these parts were subjected to the usual acceptance tests to insure aircraft forging quality. Visual and dimensional inspection was carried out on completed forgings and bent ring halves. Various nondestructive tests were tried to determine the soundness of weld. Magnetic particle inspection methods could not be used as the steels were austenitic. Results obtained with X-ray and supersonic testing could not be interpreted in terms of weld quality.

The following test procedures were used for quality control and proved entirely satisfactory. The weld upset was removed from the rings by milling; the welds were then etched in 50% HCl and examined for fissures, traces of oxide film and burning. If any of these defects were

Table 4—Percentages of Good Welds on Various Parts

Type Stainless	Cross Section, Inc.	Total Welded	% Yield
347	$^{9}/_{16} \times 2^{3}/_{4}$	923	97
347	$1^{7}/_{8} \times 1^{7}/_{8}$	21	100
321	$^{3}/_{4} \times 6$	24	54
321	$1^{7}/_{16} \times 2^{5}/_{8}$	366	60
310	$^{3}/_{4} \times 2^{1}/_{2}$	313	93
310	$1^{1}/_{8} \times 2^{5}/_{16}$	307	32
310	$1^{1}/_{8} \times 1^{7}/_{8}$	189	90

found, the rings were scrapped; otherwise they were forged. A defective weld would result in a rupture. A number of these jobs were made by pressure welding with no subsequent forging because the dimensions of the finished pieces required a rectangular cross section. As previously mentioned, a proof test devised for these consisted of expanding the undersize rings to proper diameter at low forging temperatures. Extensive investigation indicated that only satisfactory pressure welds were able to meet the test. When welds were made at too low a temperature, or an oxide film had formed at the interface, these split exactly at the weld with a flat type of fracture. Metal that had been burned during the welding process broke with a granular fracture during the expanding operation. Photographs illustrating these types of failures are shown in Figs. 19 and 20.

Table 4 summarizes the quantities produced and the yields for the various ring cross sections.

Summary

The pressure-welding process was adapted to the production of optimum quality welds in stainless steel parts for aircraft applications.

It was found essential to control surface preparation, end pressure and rate of heating to insure intimate contact of the weld faces during the initial period of the welding cycle.

Close control of temperature and gas flow, particularly with the Type 310 stainless steel, was necessary to realize the adequately high welding temperature to insure weld quality and the minimum of gradient to preclude surface burning.

A proof test of expanding or forging proved successful in insuring sound welds in that only optimum quality welds were able to meet the requirements of these tests.

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Resistance Welding for Porcelain Enameled Ware

By Ralph S. Florek*

I—General

IN THE trend to increase production efficiency and decrease unit cost, the hollow-ware enameling industry is keeping pace with improved fabrication practices. The development of resistance (flash) welding for attaching handles, spouts, ears, etc., involves two unique factors for porcelain enameled ware products. In the first place, the burning of vitreous enamel bisque at approximately 1650° F. for glass fusion, on the black iron weldment, incidentally normalizes the weld metal as well as relieves metal stresses generally. Secondly, the resultant enamel bonding increases the strength and stiffness of both the metal sections and welded joints, depending upon the thickness of enamel application. Quoting from the *Journal of the American Ceramic Society* dated June 1, 1946, article on "Stiffening Effect of Porcelain Enamel on Sheet Iron" by Don S. Wolford and Glenn E. Selby, "The increases in stiffness and bending strength ranged as high as 1500% and 500%, respectively, in the case of flat 28-gage sheet iron with 0.025 in. of enamel per side. Normal enamel thickness of 0.009 in. per side increased the stiffness and strength of flat 28-gage sheet iron about 190% and 150% respectively." It is expected, however, that these values will be lower for formed sections, in relation to the shape proportions.

Taking advantage of increased strength in final product, the use of lighter gage sheet than would be required for bare iron or nonstiffening coating, poses a problem for welding by any method. Cantilever beam load strength of attachments requires heavier gage than in the corresponding drawn shape. The unequal thickness of joint pieces was considered in experimentation with end joint design for projection-type welding. Recommended practice of projection design for height equal to light gage and diameter to heavy gage presented a tooling problem, which precludes the conventional dome or button projections.

Other important factors in hollow-ware fabrication for porcelain enameling are:

1. Minimum of heat intensity and duration to prevent scorching of metal or flashing through thin shape—and subsequent blowholes in enamel burning. Secondary buffing operation is necessary on inside of shape, if this condition develops.
2. Closed joint and projection interstices by proper pressure cycle are essential to prevent trapping of impurities or acids in pickling, and subsequent defects in the final enameled product.

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Fig. 1–7

Fig. 1—Spot-Welded Handle on Coffee Pot
Fig 2—Projection-Welded Handle on Coffee Pot
Fig. 3—Destructive Test of Welded Percolator Handle
Fig. 4—Projection-Welded Spout on Teakettle
Fig. 5—Projection-Welded Handle to Boiler Inset—in Attached Position and Destructed at Joint
Fig. 6—Spot-Welded Handle to Sauce Pan with Top Reinforcing Gas Weld to Bead
Fig. 7—Flash-Welded "Memco" Handle on Sauce-Pan

Photographic Samples are Black-Iron Shapes

3. Modification of end joint to provide vertical reinforcement by formed sections in attachments, or location on shapes at changes of section.
4. Simplification of attachment designs to permit application of one type for maximum range of shape sizes and contours—consistent with strength and appearance requirements.

Upon foregoing premises, attachment end joint designs were established with rectangular projections equal approximately to thickness of drawn shape gage at location of weldment. Said projections are one-eighth inch wide, spaced approximately twice of width or at critical points in ends of formed attachments for maximum strength. Enameled samples have verified the desired characteristics of closed joint and at spaces between projections, joint strength, minimum scorching on inside of shape, and tool life.

The varieties of shapes and methods of fabrication present opportunities for natural joint designs, using inherent projections in shape contours and forming of attachment parts. This feature will be covered fully in seamed coffee pot example.

II—Improvements in Resistance Welding

Case 1—Handle Attachments on Coffee Pot (and Percolator)

This shape is formed and seam welded longitudinally. Formed handle was spot welded to body (both top and bottom) over seam for maximum attachment strength (see Fig. 1). In addition, the handle at top carried a separately spot-welded hinge to provide space for cover clip. Three operations were required for spot welding said handle, without advantage of positioning jig on shape.

With the same shape, the handle was modified with end projections on each side of handle bottom for flash welding over seam. Handle top was left with arc blank trim, utilizing trim ends and shape seam for a three-projection joint (Plate 1, Item 2). Also, the setback at top still provided space required for cover clip, as shown in Fig. 2.

The same handle is trimmed at top for three projections one-eighth inch wide and one-thirty second inch deep at ends and middle (Plate 1, Item 1) for application

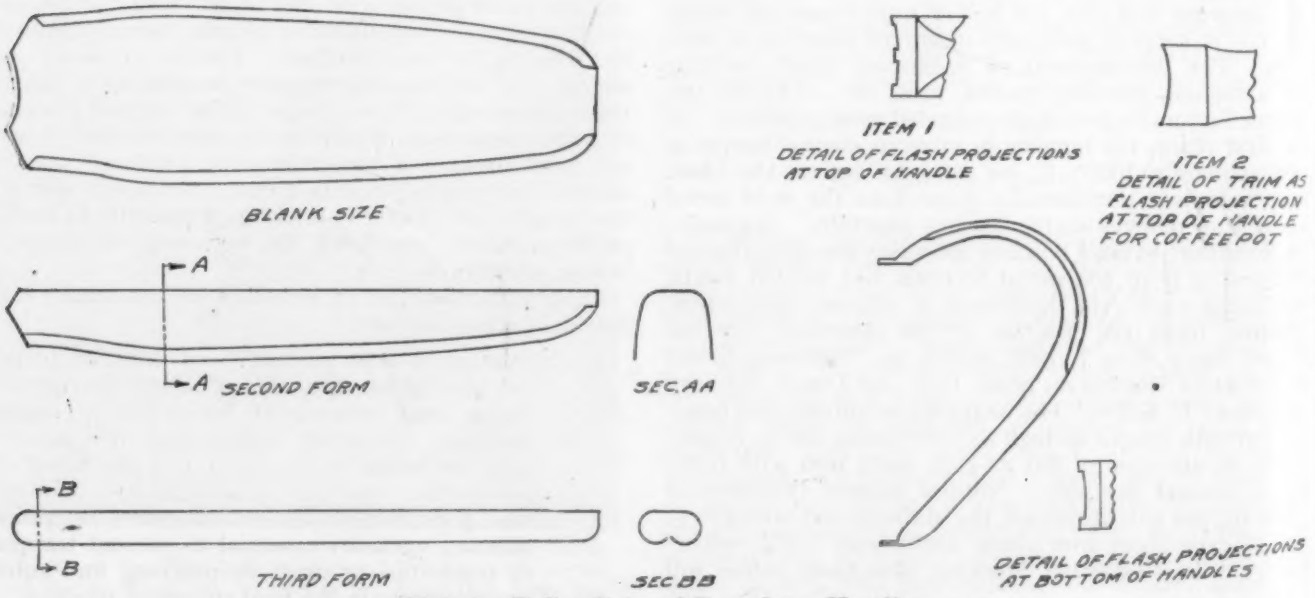

Plate 1—Coffee Pot and Percolator Handles

Plate 2—Percolator Assembly. Flash-Welded Handle in One Operation

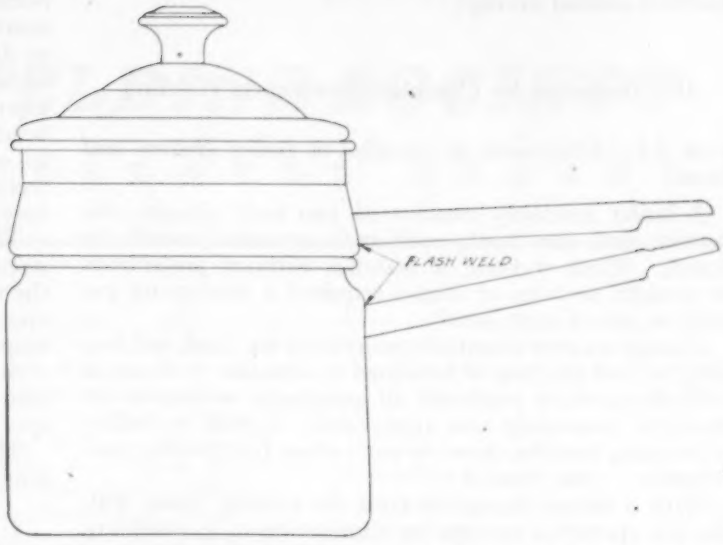

Plate 3—Boiler Assembly. Flash-Welded Handles on Bottom and Inset

on drawn percolator shapes, without seam (Plate 2). No change is made in handle bottom trim—resulting in two end projections on percolator shapes. Figure 3 shows excellent joining of handle to body.

By simplifying handle design as indicated above, common application is made for two types of coffee pots and five types of percolators.

The cost reduction effected by projection welding of this handle was appreciated by savings in a new compound form and trim die to obtain the desired top and bottom projections. Analysis of production savings are estimated below on a yearly basis:

Cost of flash weld die (using same as for previous top flash only); cost of compound die; cost of trimming die (adapt for percolators)—total $280.

Production savings—use of compound die; elimination of separate coffee pot hinge; reduce three spot welds to one flash weld on coffee pot; eliminate bottom spot weld on percolators—total $3060.

Net annual operation savings—$2780.

Evaluating reduction in rejects from welding defects alone due to semiautomatic projection welding, a conservative estimate places annual savings at approximately $13,000 on all percolators and coffee pots.

Case 2—Spout Attachment on Teakettle

A teakettle assembly requires attachment of spout to prevent leaking. Spot-welding practice on flange all-around periphery produced varying heat characteristics during manual welding cycle, and trapping of impurities between adjacent spots. Flange metal waves between spots aggravated these conditions. Changing procedure temporarily to gas welding increased cost greatly without appreciable improvement in weldment, due to dependence upon manual skill of operator and cost of heat source.

Development of spout with standard rectangular projections for flash welding to shape in one operation resulted in an acceptable joint for required characteristics of strength, enameling and appearance. (See Fig. 4.)

The extended contour of projections on spout edge to conform with spun body shape prerequisites a restrike operation on that portion of the body for the joint within tooling tolerances for trimming spout projections. Extent of projection line on spout indicates necessity for post-annealing weldment, due to enameling effects of stress relieving during burning over major shape change-in-section.

Including cost of blank, trim, form and flash dies, the net operation savings over spot welding result in $470; over gas welding $4905—on a yearly basis. Reduction of rejects due to welding defects is evaluated at $6000 annually.

Development is continuing on flash-welding projection type spouts on other items which are now spot-welded—and will show savings comparable in proportion to greater annual production quantities.

Case 3—Ear Attachments to Pails and Kettles

In the welding of ears to pails and certain kettles, it is essential to utilize strength of top formed bead as the most rigid section of the comparatively large shapes drawn from light-gage steel. The ears have a primary function for mechanical assembly with wire-formed carrying bails. Attachment of ears to bead only is inadequate due to inherent variations of beading operations and weakness in flared rim edge. Provision must be made for shakeout relief in enamel dipping from constriction between ear and bead underside.

To accommodate foregoing special requirements, an ear was designed having two button-type projections to bead and two end legs for standard rectangular projections formed at right angles to shape. The combination of projection-type joints to both bead and shape in one flash-welding operation resulted in required strength, dipping shakeout relief and minimum welding heat. An important advantage was obtained by projection welding to outside of bead arc by follow-up pressure increments compensating for bead dimension variations.

Simplification was effected by above change in design of ears for pails from spot welding on bottom apron to body only—thereby reducing inventory to one component for both pail and kettle application.

Outside of the functional improvements stated above, operation savings amount to elimination of secondary spot welding to bead on kettles. Operation cost on pails do not change appreciably, as change is from spot to flash welding only.

Based upon current quantities on all kettle items involved, it is estimated that annual operation savings of $1750 result. Evaluation of reject reductions for pail

and kettle items due to welding defects is approximately $2700 in annual savings.

III—Redesign for Complete Resistance Welding

Case 1A—Attachment of Handles to Boiler Bottom and Inset

A boiler assembly consists of two body shapes, one bottom and one inset, each with attached handle to match. Flash welding of handles without projections to straight sections of shapes required a reinforcing gas weld on top of each handle.

Change to new standard projections for flash welding (Fig. 5) and shifting of locations to shoulder sections of both shapes have produced an acceptable weldment for strength, enameling and appearance—as well as utility in bringing handles closer to each other for cooking convenience. (See Plate 3.)

With a minor change in trim die costing about $50, the net operation savings by elimination of gas welding results in $4025 on a yearly basis for four types of product items.

Evaluating reduction of rejects due to 'gas-welding defects alone, a conservative estimate is approximately $19,160 annual savings on all items in this classification.

Case 2A—Attachments of Handles to Sauce Pans

The most unique application of resistance welding was accomplished by a combination joint to shape and bead of handles to sauce pans. This handle (patent applied for) has been designated by the company as the "Memco" handle (see Plate 4) of the employee who was given a substantial award for his development of the model.

Former procedure on attaching handles to sauce pans consisted of flash welding to shape and secondary gas welding on top of handle to bead for reinforcement (detail shown in Fig. 6).

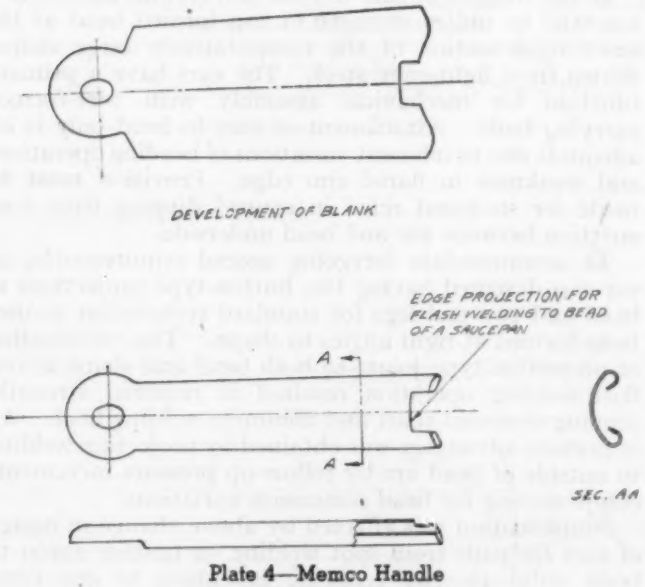

Plate 4—Memco Handle

The development of the "Memco" handle envisioned common application of one size for a maximum range of sauce pan sizes. It is necessary to consider variations in draw angles, diameters and bead sizes of shapes selected for a common handle. A feature of the handle top recess permits a chordal projection horizontally to the bead, having a zero maximum tolerance in the cutback to accommodate bead variations. Edge tolerances in recess provide close fit under bead edge for supplementary crosswire type of projection joining.

The resultant weldment takes full advantage of strength in the bead rim, in addition to the support of the two handle legs flash welded to the body—all in one operation. (See Fig. 7.) Enameling features include ample relief in cutback section, for dipping shakeout.

Substantial operation and reject-reduction savings result from elimination of gas welding and replacing three spot welds by one flash-welding operation.

These savings will be amplified as application is extended to other sauce pan groups.

IV—Summary and Conclusions

1. The approach to resistance welding for an enameled ware weldment presages the successful application of enameled coating on the black-iron shape weldment.
2. Consideration of balanced strength is inclusive with enameled strength increase increments.
3. Metallurgical incidence is obtained in normalizing weldments over-all during enamel burning operations.
4. Simplification of attachments for multiple shapes reduces cost of tooling, application and inventory.
5. Strategic location of attachments to take advantage of inherent strength in changes of section on light-gage drawn shapes.
6. Precision fabrication of formed attachments entails consideration of companion operation to tolerance on mating spun and beaded surfaces within workable allowances for satisfactory weldments by resistance welding.
7. Practicability of tooling for resistance welding practice, tool and die life, and distortion effects which might require postannealing.
8. Utilization of resistance welding offers advantages of production efficiency, cost saving and product quality for porcelain enameled ware—based upon large quantity production, reaching into several millions of aggregate product pieces per month.

V—Acknowledgments and Patent Limitations

The author wishes to acknowledge the encouragement and guidance of Mr. Walter B. Moore, President and General Manager of the Moore Enameling & Manufacturing Co. Constructive cooperation was received from the Production and Engineering Departments, particularly, Messrs. Buchman, Duff, Cass and Turner.

Any novel process or product described herein is restricted under patents and patents pending for assignment to the Moore Enameling and Manufacturing Co., West Lafayette, Ohio.

THE AMERICAN WELDING SOCIETY

ACTIVITIES – RELATED EVENTS

ANNOUNCEMENT OF WESTERN METAL EXPOSITION & CONGRESS, OAKLAND CIVIC AUDITORIUM, MARCH 22–27, 1947

A.W.S. Hotel headquarters will be shared with A.S.M. at the Hotel Leamington in Oakland, Calif.

The technical sessions of A.W.S. are scheduled to be held at the convention hall (Civic Auditorium) or at the Masonic Hall, a block and one-half away, depending on final arrangements.

Eleven hundred (1100) rooms are available in Oakland and San Francisco to date, and are being pooled with the Chamber of Commerce Housing Bureau. The address of this bureau is: Housing Bureau, Western Metal Congress & Exposition, Mr. Howard S. Sipe, Manager, Convention & Tourist Dept., 417—14th St., Oakland 12, Calif. (California Hotel Association requires $5.00 deposit with reservation of each room.)

The seven hotels available near these halls in Oakland are: City Club Hotel, Hotel Coit-Ramsey, Hotel Harrison, Lake Merritt Hotel, Lakehurst Hotel, Hotel Leamington, Olympic Hotel, Hotel St. Mark.

Program—an A.W.S. program of meetings, events, etc., is being printed separately for mailing to AMERICAN WELDING SOCIETY membership.

A.W.S. luncheon, Monday noon, March 23rd, will be held in Oakland at the Hotel Leamington or Masonic Hall. At this luncheon distinguished guests from San Francisco and the Bay District will be invited in addition to A.W.S. members attending the convention. Presentation of Lincoln Gold Medal to H. E. Kennedy and recognition of San Francisco Section's 25th anniversary will be made.

Wednesday evening A.W.S. will join A.S.M. and other technical societies in a banquet and ball at the Palace Hotel in San Francisco. Preceding this dinner, the AMERICAN WELDING SOCIETY has reserved a large room for a get-together and cocktail hour for A.W.S. members exclusively at the same hotel.

NOMINATING COMMITTEE

With the approval of the Board of Directors the President has appointed the following members to constitute the 1946–47 Nominating Committee: W. F. Hess, *Chairman*, Rensselaer Polytechnic Institute, Troy, N. Y.; A. E. Gibson, Wellman Engineering Co., 7000 Central Ave., Cleveland, Ohio; I. Harter, The Babcock & Wilcox Co., Barberton, Ohio; E. B. Stolle, Midwest Piping & Supply Co., 30 Church St., New York 7, N. Y.; J. J. Chyle, A. O. Smith Corp., Milwaukee, Wis.; J. Lucas, Southwest Welding & Mfg. Co., Inc., 3201 W. Mission Rd., Alhambra, Calif.; A. J. Moses, Hedges-Walsh-Weidner Div., Combustion Engineering Co. Inc., Chattanooga, Tenn.

The By-Laws require that these names be published in the JOURNAL on or before March 1st. The Committee is required to deliver to the Secretary in writing on or before the 10th day of May, the names of its nominees for the various elected offices next falling vacant, together with the written acceptance of each nominee.

The purpose of publishing the names of the Nominating Committee in the JOURNAL is to provide every member with an opportunity to make suggestions to the Nominating Committee. To be effective it is essential that these suggestions be sent in at once as, naturally, the Nominating Committee will be required to hold early meetings in order to fulfill its duties as required by the By-Laws.

The offices to be filled are: President, First Vice-President, Second Vice-President (all for a term of 1 year), Treasurer and four Directors (all for a term of three years). Present incumbents of the offices of President and Treasurer are eligible for another term. The incumbents for First and Second Vice-Presidents and Directors-at-Large are not eligible for re-election, according to the By-Laws, Article VIII, Sections 3 and 6, respectively. The Directors-at-Large are selected by the Nominating Committee, with due consideration to geographic distribution.

Present officers whose terms expire next October are: *President*, L. W. Delhi; *First Vice-President*, H. O. Hill; *Second Vice-President*, G. N. Sieger; *Treasurer*, O. B. J. Fraser. *Directors:* R. W. Clark, J. F. Lincoln, R. S. Donald, H. M. Priest.

MINUTES MEETING BOARD OF DIRECTORS AMERICAN WELDING SOCIETY

Held at the Hotel Ambassador, Atlantic City, N. J., November 22, 1946

The meeting was called to order by President Delhi at 3 P.M. with the following present:

Members—C. A. Adams, D. H. Corey, F. W. Davis, O. B. J. Fraser, W. F. Hess, H. O. Hill, G. O. Hoglund, J. F. Maine, R. E. McFarland, L. S. McPhee, H. W. Pierce, C. P. Sander, G. N. Sieger, H. N. Simms and R. D. Thomas.

Staff—W. Spraragen, Director, W.R.C., L. M. Dalcher, Technical Secretary, A.W.S.

Introduction of New Officers and Directors

Mr. Delhi introduced the new officers and directors present.

Appointments

Recommendations for appointment for Secretary and Assistant Treasurer and 1946–47 standing committees of the AMERICAN WELDING SOCIETY were distributed in advance of the meeting. These will be printed in the Year Book.

It was voted to submit the name of Mr. R. S. Donald to the Board of Directors for letter ballot vote to fill the unexpired term of Mr. L. W. Delhi on the Board of Directors.

It was, upon motion, duly seconded, voted to approve the list of appointments, including the Secretary and Assistant Treasurer and standing committees.

Signing of Checks, Notes and Other Documents in Behalf of the Society

It was voted to designate the Treasurer and Assistant Treasurer, and in the absence of either, the First Vice-President, as signers of checks, notes and other documents as prescribed by the by-laws.

Board Meetings

It was voted to approve the suggested Board meetings and Executive Committee meetings, which were listed on the agenda as follows:

Board Meetings: November 22nd—Atlantic City; February—Detroit; March—San Francisco; May—Chicago; September—New York.

Executive Committee Meetings: December—New York, for approval of annual budget; April—New York, leaving open months June through August for any emergency that might arise with the understanding that the Secretary would canvass the members of the Board of Directors well in advance, with the idea of making sure that a quorum would be present.

The President authorized Mr. Hill to call a meeting of the Executive Committee in December for the purpose of approving the 1946–47 budget and taking care of other items which may come before the Executive Committee.

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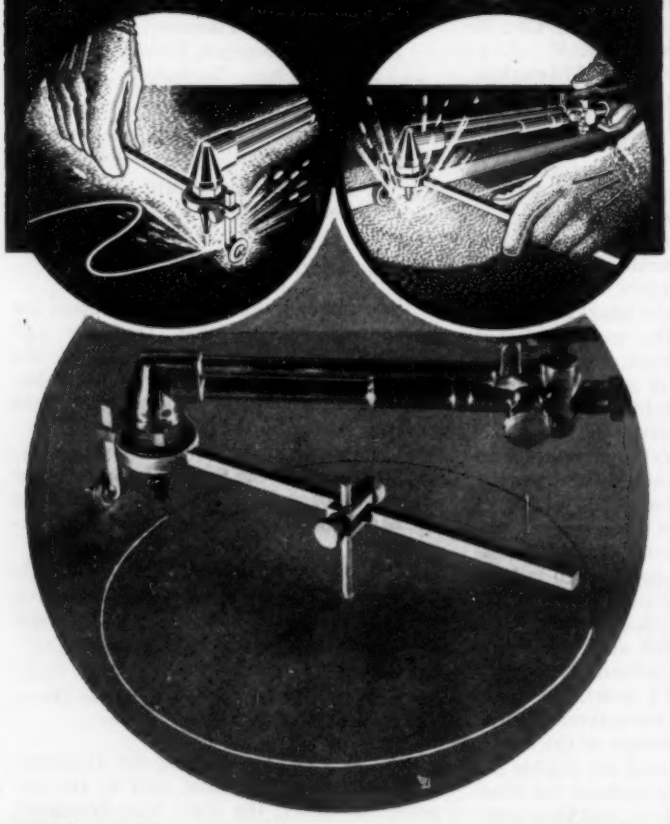

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In the listing of the Board meetings, it was suggested that the February meeting be listed as February 14th, the March meeting as some time between the 17th and 22nd, and the May meeting on the 16th.

Adjournment

The meeting adjourned at 3:45.

A.W.S. AUTOMOTIVE WELDING COMMITTEE

The AMERICAN WELDING SOCIETY Automotive Welding Committee recently put into effect a plan whereby inspection trips are held in conjunction with its regular meetings, by visiting the River Rouge plant of the Ford Motor Co. on Dec. 5, 1946.

A fairly complete tour was made of the welding operations followed by a quick look at the general facilities while touring the plant in a glass-roofed bus. The accompanying photograph shows the Committee at the completion of its visit.

The hospitality of the Ford Motor Co. in providing every possible convenience for the Committee made the trip most enjoyable and enlightening and it was agreed that more such visits to automotive plants be scheduled.

DUTCH WELDING CONGRESS

Word has been received from Professor H. E. Jaeger, Rotterdamsche Weg 101, Delft, Netherlands, of a Welding Congress or "Welding Symposium" to be held in June 1947 in Utrecht (Object—Fired and Unfired Pressure Vessels). This Welding Congress will be sponsored by the Nederlandsche Vereeniging voor Laschtechniek (Dutch Welding Society), which Society plans a more intensive contact with foreign Welding Societies. Further information regarding the Welding Congress may be obtained by writing to Professor Jaeger, care of the above address.

ABORN PROMOTED

The appointment of Dr. Robert Hollenbeck Aborn as assistant director of the Research Laboratory, United States Steel Corp., at Kearny, N. J., was announced recently by Dr. R. E. Zimmerman, vice-president in charge of research and technology. A native of Battle Creek, Mich., Dr. Aborn graduated from Grinnell College, Iowa, in 1918, and in 1920 won a B.S. degree and in 1925 a degree of Doctor of Science at Massachusetts Institute of Technology.

Employed in the blast furnace department of Bethlehem Steel Co. in 1920, Dr. Aborn was employed at the Watertown Arsenal in 1923 and in 1925 returned to conduct research at M.I.T. In 1928 he became an instructor at the engineering school at Harvard University, leaving that post to join the Kearny laboratory of U. S. Steel in 1930. Prominent in welding research, Dr. Aborn won the Lincoln Medal of the AMERICAN WELDING SOCIETY in 1941 and during the war served for a year on the War Metallurgy Committee of the Office of Scientific Research and Development.

DATA BOOK ON ALUMINUM ALLOYS

Due to the tremendous demand for technical information on aluminum alloys, Reynolds Metals Company has published a 248-page book featuring 106 tables of technical data. After describing briefly the history of aluminum, the book discusses alloy tempers, physical properties and presents detailed data on chemical, physical and mechanical properties of high purity aluminum; with nominal chemical compositions, typical mechanical properties, values of density of coefficients of expansion, thermal and electrical conductivity, annealing and heat-treating cycles for wrought, sand-casting, permanent-mold casting, and die-casting alloys.

Subsequent chapters then take up various mill products, covering such subjects as manufacturing methods, alloys and tempers in which that product is made, identification, packing, ordering data, commercial and standard sizes, specified chemical compositions, specified mechanical properties, commercial size and thickness tolerances, weights, weight conversion data, bend radii, pressure calculations (for tubing and pipe), and similar information.

Sections are devoted to the following mill products: Sheet and plate, extruded shapes; roll formed shapes; tubing and pipe; wire, rod and bar; forging stock; ingot metal; press forgings. In addition, a group of reference tables includes a comparison of gages; decimal equivalents; shrinkage allowances for castings; relative weights of various metals; principal characteristics of various wrought aluminum alloys in sheet form and also as forging alloys.

A section on related specifications is arranged according to alloy designations. Then these are broken down into the vari-

Meeting Automotive Welding Committee, A.W.S.

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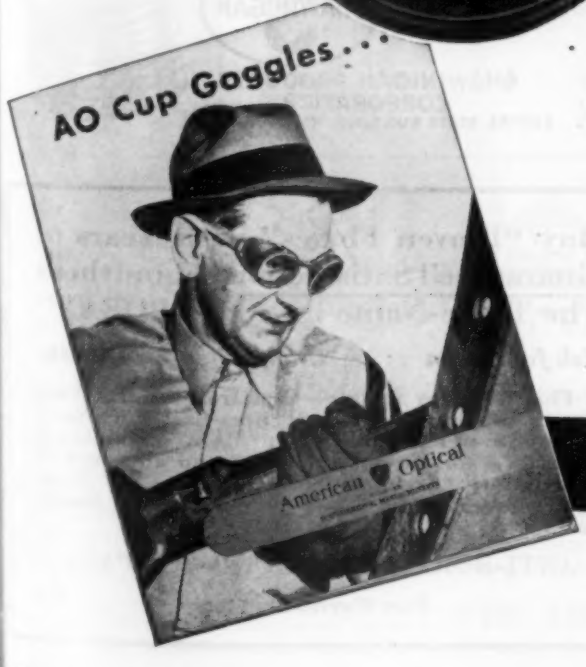

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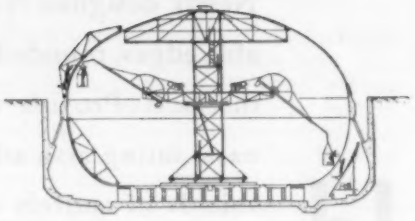
ous product forms and related specifications applying are listed, including Federal, Army and Army Air Forces, Navy, Army-Navy (AN) Aeronautical, S.A.E. Handbook, A.M.S., and A.S.T.M. specifications.

A novel feature of the book is the color index scheme employed to facilitate location of the various material. A color flag appears on each 2-page spread that ties in with a color index in the front of the book to speed the locating of any particular section wanted.

Like other Reynolds technical manuals this 248-page, 6 × 9-in. book is wire bound to open flat at any point. It contains a detailed table of contents, a thorough cross index, and a separate listing of the 106 tables. The books are available from Reynolds Metals Company, Dept. 47, 2500 So. Third Street, Louisville 1, Ky. Price $2.00

FRENCH SOCIETY OF WELDING ENGINEERS

A joint meeting of the French Society of Welding Engineers and the Belgian Institute of Welding was held in Paris, February 15, 1946. A lecture entitled "Some Theoretical Considerations on the Deformation and Static Rupture of Metals" was delivered by Professor W. Soete, of the University of Ghent, who had just returned from a trip to the United States.



On May 3rd, there was a joint meeting of the French Society of Welding Engineers and the French Association of Petroleum Technologists. Two papers were presented, The first was by M. A. Caquot. "The Problem of Storage Tanks for Combustible Liquids." Two different designs are best suited for tanks completely filled with liquid or compressed gas. The first design is the sphere. The second has the shape of a drop of water lying on a plain surface. The second type of tank is the more economical, and the welding of a 120,000-cu. ft. tank, designed by Caquot, is described by Gerbeaux. The storage tank is 70 ft. in diameter and 45 ft. high. The two-torch vertical method of oxy-acetylene welding was employed (Fig. 1) to a large extent in the field erection of the sides of the tank. This method was adopted because it assured perfect welded joints despite irregular fit-up of the plates, which were $^1/_4$ to $^3/_8$ in. thick.

METCO NEWS

The January issue of the *METCO News*, published quarterly by Metallizing Engineering Co., Inc., Long Island City, describes the greatly varied uses (from pump liners to push buttons) that a major oil refinery has made of metallizing over a 12-year period; also, the metallizing of plywood to form electrodes of a table that tests rubber blankets at 10,000 volts; copper metallizing of cast-iron core boxes to eliminate core oil trouble in making castings; solving the problem of protecting the welded seam in steel barrels and drums through production metallizing; protecting aircraft engines against atmospheric corrosion and salt spray; and a "Technical Talk" on a method for improving the adhesion of sprayed metal to blasted surfaces.

WELDABILITY OF 313 COPPER-BASE ALLOYS LISTED BY TRADE NAMES, MANUFACTURERS

One of the most comprehensive compilations of welding and composition information relating to copper-base alloys is a set of 19 mimeographed sheets just issued by Ampco Metal, Inc., Milwaukee, Wis., entitled "Weldability and Composition of 313 Copper-Base Alloys."

The list gives trade names, manufacturers and chemical composition of most

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Monel to 18/8 Stainless Steel
Metal Arc Weld with . . . . "130X" Monel Electrode or
"131" Nickel Electrode

Nickel to 18/8 Stainless Steel
Metal Arc Weld with . . . . "132" Inconel Electrode or
"133" 80/20 Nickel-Chromium Electrode

Inconel to 18/8 Stainless Steel
Metal Arc Weld with . . . . "132" Inconel Electrode or
"133" 80/20 Nickel-Chromium Electrode

Monel to Nickel
Metal Arc Weld with . . . . "130X" Monel or "131" Nickel Electrode
Oxy-Acetylene Weld with "40" Monel or "41" Nickel Gas Welding Wire and INCO "1" Flux

Monel to Inconel
Metal Arc Weld with . . . . "130X" Monel or "131" Nickel Electrode
Oxy-Acetylene Weld with "40" Monel or "41" Nickel Gas Welding Wire and INCO "2" Flux

Monel to Cast Iron
Metal Arc Weld with . . . . "Ni-Rod" Electrode

Nickel to Cast Iron
Metal Arc Weld with . . . . "Ni-Rod" or "131" Nickel Electrode

Nickel to Inconel
Metal Arc Weld with . . . . "131" Nickel or "132" Inconel Electrode
Oxy-Acetylene Weld with "42" Inconel Gas Welding Wire and INCO "2" Flux

*Reg. U. S. Pat. Off.

INCO
TRADE MARK

USE THIS HANDY TABLE

It's a useful guide to help you pick the right electrode or welding wire.

Calls often come through for welding Monel, nickel or Inconel to a different metal...particularly in lining work...and sometimes the demand is for a vessel lined with one metal in the top and a different one in the bottom.

You'll find the proper welding material for such jobs listed in the handy table.

Many other welded construction call for INCO Nickel Alloys used in conjunction with different metals. For example, your customer may want stainless steel supporting members welded to a nickel still.

Keep the table handy...it simplifies choosing exactly the right electrode or welding wire for each job. But remember that the success of many dissimilar joints depends on the way they are made. If you want a complete outline of the welding procedures required on your particular job, just send the details of the joints you must make to INCO's Technical Service Division.

And for a detailed over-all picture of how to weld the INCO Nickel Alloys, write for Technical Bulletin T-2. It's yours for the asking.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 WALL STREET NEW YORK 5, N. Y.

of the established copper-base alloys together with such welding information as degree of weldability, preheats, type of electrodes or rods recommended and the preferred welding process.

This list was primarily prepared and issued for use by distributor welding engineers. However, Bulletin D-2383 will be sent to all interested welders and welding engineers upon request.

NEW WELDED PASSENGER SHIP

The SS *Del Norte*, finest luxury liner to be built for the New Orleans–South American run, made her maiden voyage late in November (cover picture).

Constructed by The Ingalls Shipbuilding Corp. at its Pascagoula, Miss., yard—first one designed for the exclusive use of the all-welded method of building ocean liners—the gaily painted vessel was scheduled to be delivered by Ingalls to Delta Lines (Mississippi Shipping Co.), of New Orleans, about November 15th. She will be on exhibit at the Louisiana port during International Week, a Good Neighbor program designed to bring together officials off the Americas.

The vessel is the first of three sister ships being built by Ingalls, which also is busy on a $37,000,000, 14-ship contract for Lloyd Brasileiro, Brazilian Government ship line; four 352-ft. hopper dredges for the Army Engineers and two cargo-passenger vessels in a fleet of seven for Moore-McCormack, the other five built at Pascagoula already having been delivered.

The *Del Norte*, designed by George G. Sharp, prominent New York naval architect, has the latest navigational and safety improvements, including radar, and features a number of refinements for passengers, including air conditioning throughout, all outside bedrooms with private bathrooms and showers, swimming pool, shopping center and elevators.

The luxury liner, along with her sister ships, *Del Sud* and *Del Mar*, will be used by Delta Line on 47-day cruises from New Orleans to Buenos Aires and return with stops at Rio, Montevideo, Santos, Martinique and Trinidad.

One of the most distinctive features of the 494-ft. liner is the huge tear-shaped stackhouse which takes the place of the conventional "smokestack." In the first place, the false stackhouse is constructed of aluminum, an innovation, and, in the second place, it has nothing to do with smoke and gases, which will be disposed of high above the deck through two pipes resembling kingposts, minimizing the unpleasant results of dirt and soot in the passenger deck areas.

Directly below the top of the stackhouse, there are living quarters for the radio operators; the radio rooms and emergency generator also are located in the false stackhouse, which has no windows and relies entirely on the air conditioning system for air circulation and control. These quarters, in keeping with others for the crew and 120 passengers, are finely furnished with ceramic tile showers and toilet facilities; fixtures are chrome plated and the deck covering in these spaces is of vinylite, providing safe, resilient footing.

Passengers may make a complete circuit of the ship on the unusually wide promenade deck, the forward part of which is enclosed against inclement weather. The air-conditioned staterooms have individualized controls. Many of the 30-ft. long rooms are divided into two distinct sections, one for daytime lounging and the other for sleeping. Also, there is an extra folding bed in each stateroom to take care of a child or extra person.

As for the public rooms, the dining room, the lounges, the bars, and so forth, the ship offers the last word in luxurious accommodations. The spirit of fabulous New Orleans, home port of the ship, is evident everywhere. The dining salon, located amidships for the greatest stability, is colorful and inviting with its New Orleans decoration. Four large white plaques, containing the coats of arms of

STAR-SPANGLED SHIP

This huge new luxury liner made an impressive sight in this night scene taken just before she was launched at the Ingalls Shipbuilding Corp. yards in Pascagoula, Miss. The all-welded, 495-ft. ship, first luxury liner to be launched since the war, will be placed on the New Orleans–South American run by Delta Line this winter.

A Portion of the Grand Salon Aboard the New Ingalls-Built Liner *Del Norte* Shows the Comfortable Appointments That Are Characteristics of the Luxury of the Three New Passenger-Cargo Liners Build at Ingalls' Pascagoula Yard for Delta Lines, Inc., of New Orleans

"ELECTROLOY" for RESISTANCE WELDING

Butt
Flash
Spot
Seam
Projection

ELECTROLOY

Catalog and prices on request

OFFSET HOLDER

THE ELECTROLOY CO. INC. 1600 SEAVIEW AVE. BRIDGEPORT, CONN. WELDING ROLL

Welds 20% Faster with New AC-DC Electrode

IN the fabrication of bases and other parts, Cleveland Automatic Machine Company reports welding speed increases of as high as 20% with the new Lincoln "Fleetweld 47" Electrode. The majority of this welding is flat and horizontal fillets with AC. In the fillet welding of guides to ½" plate for bases (Fig. 1), arc speed is 13" per min. with the ¼" electrode.

Because of the smooth, flat appearance of the beads, this manufacturer also uses this AWS Class E-6013 electrode for finish passes of multiple-pass welds in heavy plate (up to 4" thickness).

AC or DC is used. In case of DC, polarity is electrode negative. Slag removal is so easy, welds are practically self-cleaning, the Company reports.

For flat welding, first or single pass welds, use sufficient current so electrode does not stick, and hold a very short arc or lightly drag coating on the plate. Hold electrode as shown in Fig. 2 and travel forward rapidly to stay ahead of molten pool.

In making horizontal fillets, make the weld "feather" into the vertical plate. This is done by lightly dragging the coating on the flat plate and maintaining a 1/16" to ⅛" space between the electrode and the vertical plate.

When using "Fleetweld 47" for vertical vee butt or fillets, better penetration and appearance and greater speed can be obtained by using a single pass weave (Fig. 3) rather than a multiple pass whipping technique.

Fig. 1. Fillet welding guides to base with new "Fleetweld 47" electrode.

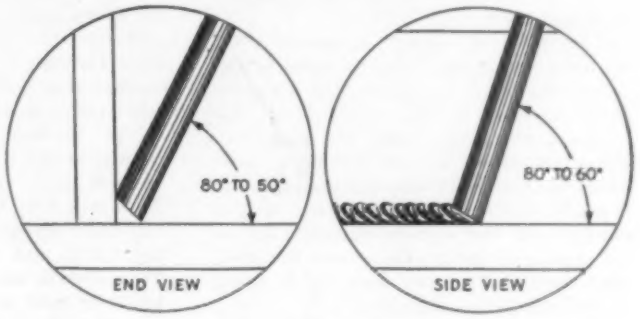


Fig. 2. Angle of electrode to work for horizontal fillets.

Do not remove the arc from the molten pool while making the weld. Weld vertically up only. Keep the molten pool tilted up into the corner so that the slag all runs to the outer edge. On ¾" plate or thicker, put in ½" weld in one pass and then weave back and forth across the face for as many passes as are required to bring weld up to size.

Fig. 3. Single pass weave for vertical welds.

For overhead fillets and horizontal butts, use stringer beads. A slight circular motion to the whip will prevent undercut on the upper edge on the larger size single pass fillets.

Lincoln Engineers will assist in the application of this new electrode. Complete details and procedure for "Fleetweld 47" and other Lincoln Electrodes are given in the Weldirectory. Free on request from THE LINCOLN ELECTRIC COMPANY, Dept. 122, Cleveland 1, Ohio.

the four nations which have held the city during her turbulent history, hang against a wall draped in velvet. Giant magnolias, 30 in. wide, provide the ceiling lighting, supported by spotlights directly illuminating the diners' tables. The picture wallpaper, specially designed for the *Del Norte*, depicts scenes of the Mississippi delta.

The motif of the main hall is also inspired by the Crescent City, as shown in the linoleum carvings of the exotic plants and wildlife of the Louisiana Low Country. In the festive club room and bar, a long mural by New Orleans-born Paul Ninas captures the spirit of Mardi Gras, and in the deck cafe Ninas' Louisiana scenes provide restful green leaves, a very welcome feature at sea.

An elevator, adjoining the beautiful spiral staircase, will take passengers down from their deck to meals on the second deck and up to the facilities on the promenade and boat decks.

The ship's officers will be quartered on the boat and navigating decks and in the false stack, while the rooms for the crew of 124 men are on the second deck. All of these rooms are, like the passenger accommodations, as comfortable as possible, each with its air-conditioning unit. Separate messes will take care of the officers and the various departments of the crew. There is also a crew hospital, with facilities for six men at a time, located on the second deck.

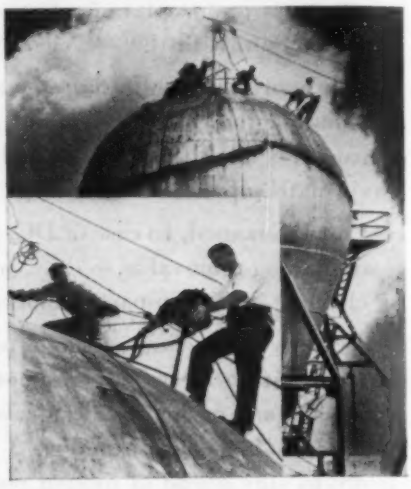
The general appearance of the *Del Norte* shows a marked improvement over the prewar luxury liners. The vessel has a modified C-3 type hull of the U. S. Maritime Commission, together with a cruiser stern and a slightly curved raked stem. Of all-welded construction, except for the stack and the gunwale angles on the shelter deck, the *Del Norte* is a thoroughly substantial ship. Eight watertight bulkheads subdivide her, meeting the requirements of the 1929 Convention for Safety of Life at Sea and of the U. S. Coast Guard. An additional watertight bulkhead between Nos. 3 and 4 holds makes the *Del Norte* a two-compartment vessel.

With excellent cargo facilities, the *Del Norte* is as welcome to export shippers as she is to travelers. There are six nonrefrigerated holds with a capacity of 457,690 cu. ft. of cargo and a refrigerated hold that can carry 61,390 cu. ft. of cargo. The bulkheading and linings are of fire-resistant construction, and, for added safety, there are fire detectors throughout the cargo space. The machinery space is protected by a carbon dioxide extinguisher while the cargo spaces are provided by a combination carbon dioxide and smoke-detecting system.

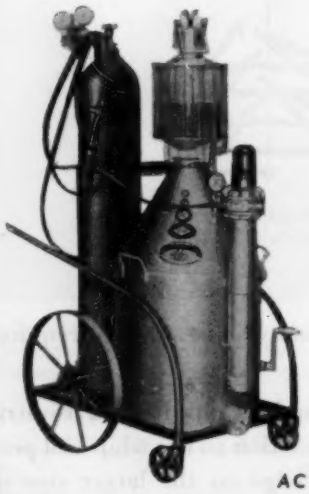
The ship has a length of 494 ft. and a breadth of 69 ft., with a total displacement at load draft of 16,715 tons. The *Del Norte* can take 6820 cu. ft. of mail, and will carry 160 tons of drinking and washing water and as much reserve water. To maintain her designed speed of 16½ knots or more at sea, she will carry 2220 tons of fuel oil when the tanks are 98% full. In addition, there are about 20 tons of lubricating oil and Diesel oil.

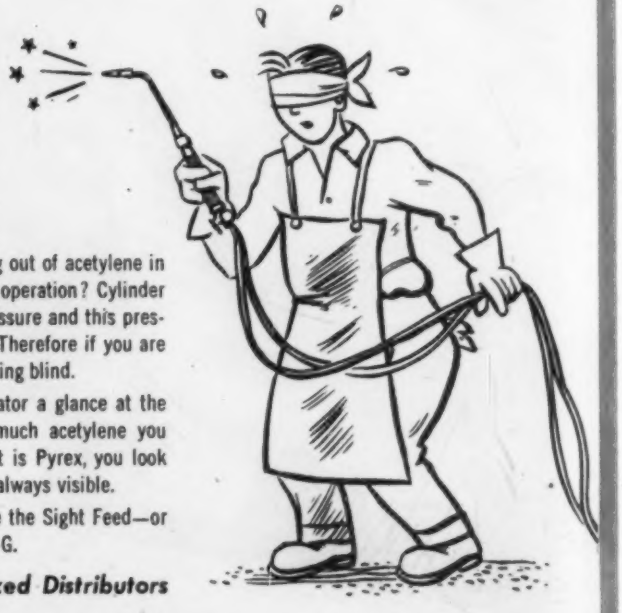
ATOM SMASHER GETS A "CHEST X-RAY"

Nonchalant as veteran mountain climbers roped together at their task, research men prepare to take a "chest X-ray" of the 65-ft.-tall atom smasher at the Westinghouse Research Laboratories. The giant electrostatic generator is being readied for use in the broad program of fundamental research in nuclear physics now being carried on by Westinghouse scientists. Here Dr. Fitz-Hugh Marshall, Westinghouse research engineer, assisted by technician Floyd Craig, sets up the "camera" for one of the



Why Weld Blind?





● Would you take a chance on running out of acetylene in the middle of a welding or cutting operation? Cylinder gages show you only the available pressure and this pressure holds up until the last few feet. Therefore if you are using "bottled" acetylene you are welding blind.

With a Sight Feed Acetylene Generator a glance at the hopper will tell you instantly how much acetylene you have available. Look at the hopper, it is Pyrex, you look through it, not into it. The carbide is always visible.

Stop at your jobber's store and see the Sight Feed—or write for free 16-page catalog No. 44-G.

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THE SIGHT FEED GENERATOR COMPANY

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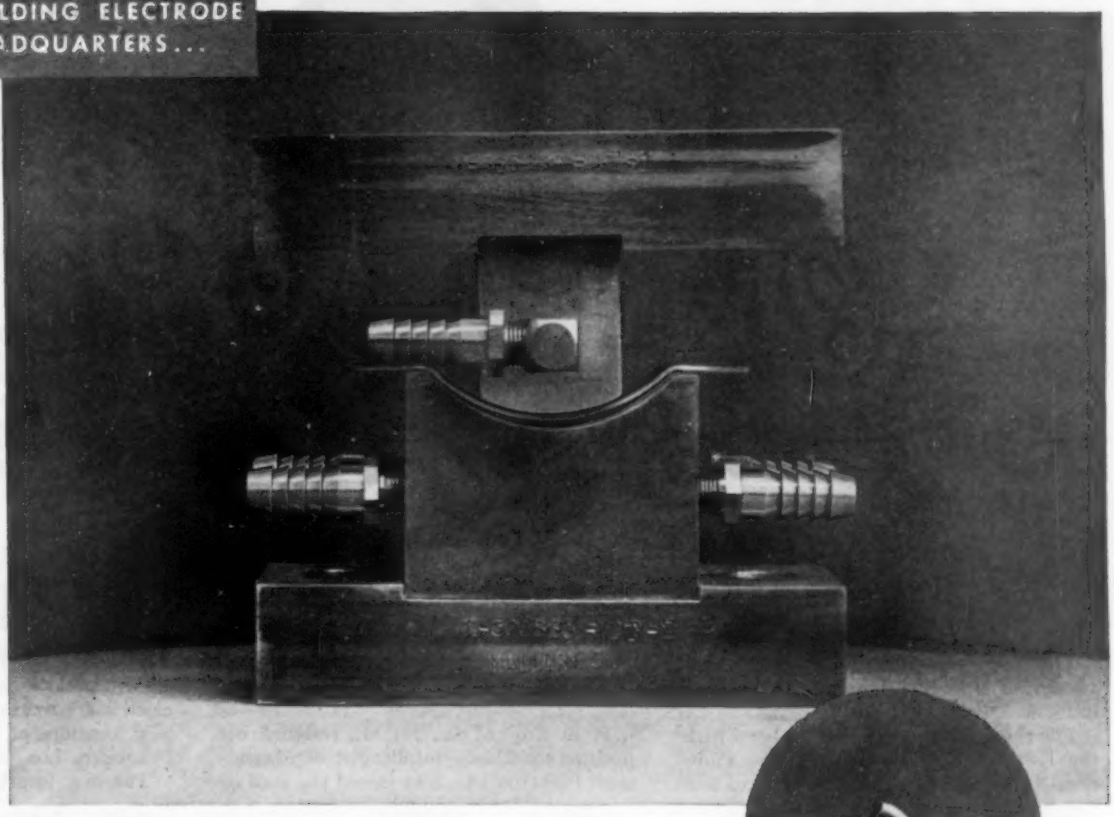
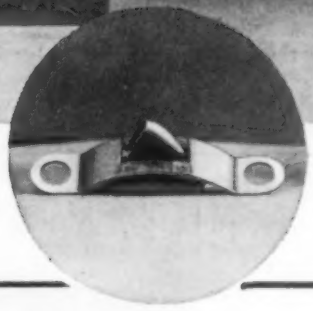
HEADQUARTERS...





We Build Long Life into Projection Welding Dies

There's more to building resistance welding dies than meets the unpractised eye. There's the matter, for instance, of making them of *proper materials* so they won't deform or wear out quickly.

Mallory has been a pioneer in the development of alloys having high electrical conductivity—alloys that withstand elevated temperatures and pressures over prolonged periods of operation. Two materials in particular—Elkonite* and Mallory 100 Metal—are world-famous for their ability to stand up under heat and abrasion: to produce thousands of welds before redressing is necessary. Projection welding dies faced with these materials maintain their contour through long production runs.

That's why, when there's a problem of die designing, manufacturers turn to Mallory. Long life is built into Mallory dies. No company has greater experience in developing resistance welding electrode materials . . . does more research . . . serves more industries . . . is more willing or able to be of help. Submit your resistance welding die problems to Mallory.

In the United Kingdom, made and sold by MALLORY METALLURGICAL PRODUCTS, LTD.
(An Associate Company of Johnson, Matthey & Co., Limited), Hatton Garden, London, E. C. 1.

P. R. MALLORY & CO., INC., INDIANAPOLIS 6, INDIANA

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MALLORY

ELECTRODES — HOLDERS — SPECIAL DIES AND FIXTURES — ELKONITE*— ALLOY ROD AND BAR STOCK — FORGINGS — CASTINGS — ACCESSORIES

*REG. U. S. PAT. OFF.

RESISTANCE WELDING MATERIALS

X-ray shots which reveal the soundness of the welded seams in the huge outer tank. The close-up view shows Dr. Marshall aiming the X-ray tube at the seam under examination while inside the tank a film strip is being placed in position for exposure. Cables in the background carry 140,000 v. of electricity to operate the X-ray tube which is similar to the type used in hospitals for treatment of cancer. A 30-sec. exposure provides a picture that would show any flaw in the tank's welded seams. Following completion of its "physical checkup" the atom smasher will be put back into operation exerting its "strength" of 4,000,000 v. to hurl electrified particles at fantastic speeds approaching 100,000,000 miles an hour.

LANG JOINS LUKENWELD

John L. Lang, a member of A.W.S., has joined the staff of Lukenweld, Inc., a division of Lukens Steel Co., as Welding Engineer, it was announced by R. W. Moffett, General Manager of Fabrication.

Mr. Lang was graduated from the University of Illinois School of Engineering in 1930.

For the last five years he has been with the New York Shipbuilding Corp., Camden, N. J., as Supervisor of Chemical and Metallurgical Laboratory and as Assistant to the Welding Engineer.

John L. Lang

FOX JOINS BRITISH WELDING RESEARCH ASSOCIATION

F. A. Fox, M.Sc., F.I.M., resigned his position as Chief Metallurgist of Magnesium Elektron Ltd. and joined the staff of the British Welding Research Association in January as Assistant Director of Research. His main concern will be with the metallurgical work of the Association. Mr. Fox has been engaged in metallurgical research since 1934, in both the ferrous and nonferrous fields, and has had considerable experience in the organization of this kind of work. He has been responsible for many publications, mainly in the light alloy field, a number of which have appeared in the *Journal of the Institute of Metals*. Mr. Fox has been active in research on light-alloy welding since 1940.

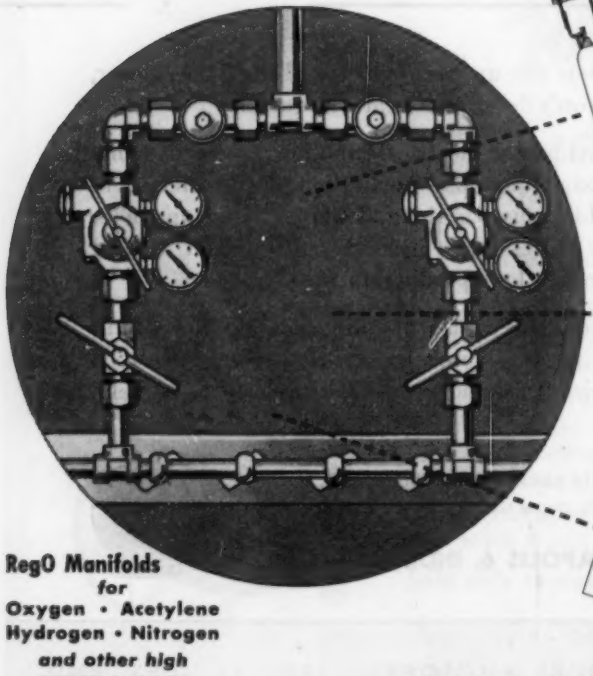
ELECTRODE CHART

The Champion Rivet Co. has recently published a new Comparative Chart covering their welding electrodes. Copy of same may be had by writing direct to The Champion Rivet Co., E. 108th St. and Havard Ave., Cleveland 5, Ohio.

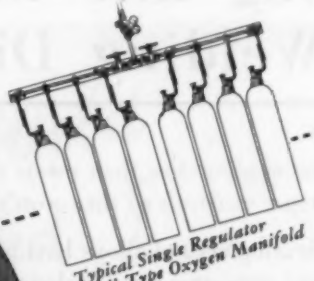
LINCOLN ELECTRIC ANNOUNCES NEW LOCATIONS OF DISTRICT OFFICES

The Lincoln Electric Co., Cleveland, Ohio, world's largest manufacturer of electric arc welding equipment, announces new locations of its branch offices in San Francisco, Los Angeles and Birmingham.

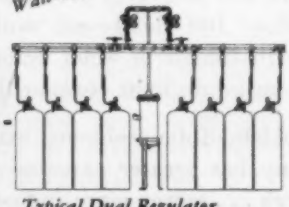
The new location of the San Francisco



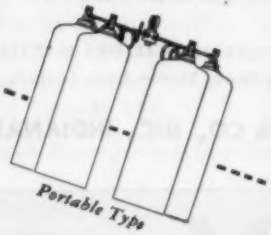
RegO Manifolds for Oxygen • Acetylene Hydrogen • Nitrogen and other high pressure gases



Typical Single Regulator Wall-Type Oxygen Manifold



Typical Dual Regulator Floor-Type Acetylene Manifold



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REGO CONSTRUCTION PRODUCES BETTER MANIFOLDS

● RegO design means safe performance, long life and low maintenance costs. Here are some of the construction features you get when you specify RegO Manifolds...

Unit Construction... The header section of each RegO Manifold is virtually one-piece; extra-heavy seamless brass pipe is run through the forged brass header fittings, the cylinder station shut-off valves and the master shut-off valves...all permanent connections are then silver-brazed. The header assembly is bolted to a heavy steel I-beam to assure permanent alignment.

Precision Regulation... large capacity two-stage RegOlators assure constant and uniform delivery pressure to the pipe system.

Extra Convenience... standard RegO Manifold construction provides individual shut-off valves at each cylinder station...this design permits any one cylinder to be disconnected without shutting down the entire manifold. Master shut-off valves control each main branch.

Rigid Tests... header pipe, valve bodies and fittings withstand pressure up to 10,000 psi and each complete RegO Manifold is subjected to a sustained air pressure test up to 2,000 psi.

There Is A RegO Manifold to Fit Your Most Exacting Requirements

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PAGE *Welding* ELECTRODES

This is the latest PAGE announcement

For further information see your PAGE Distributor

PAGE NI-CAST SHIELDED ARC ELECTRODES

Will Produce Good Machinable Welds On All Types Cast Iron. Useful for Repairing Broken, Worn or Defective Castings.

MONESSEN, PA.—The soft weld metal deposited by this new PAGE electrode bonds perfectly with all grades of cast iron. This makes it invaluable for repairing broken, worn or defective castings, and for correcting errors made in machining. After machining or grinding, the weld metal deposit closely matches the color of the cast iron parent metal.

The core wire is 99% nickel. The coating is free of fluorides and other ingredients which generate injurious gases.

These new PAGE Ni-Cast Shielded Arc Electrodes are made in 3/32″, 1/8″, 5/32″ and 3/16″ diameters. They are packed in 10-pound cartons.

Announcement Number Nine

This is the latest of nine announcements made by PAGE *in the past twelve months. For information about* PAGE *welding electrodes or gas rods or about their most efficient use, get in touch with your* PAGE *distributor.*

ACCO

Monessen, Pa., Atlanta, Chicago, Denver, Detroit, Los Angeles, New York, Philadelphia, Pittsburgh, Portland, San Francisco, Bridgeport, Conn.

PAGE STEEL AND WIRE DIVISION
AMERICAN CHAIN & CABLE

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office and warehouse is at 1302 Stanford Ave., Emeryville 8, Calif., under the direction of L. P. Henderson, district manager and welding engineer.

The Los Angeles office and warehouse is now located at 1500 Calzona St., P. O. Box 7336, Station L, Los Angeles 23, Calif. J. B. McCormick is district manager and welding engineer.

The Birmingham district office has its new location at 113 N. Ninth St., Birmingham, with J. E. Durstine the district manager and welding engineer.

EUTECTIC "LOW TEMPERATURE" WELDING RODS*

A new brochure, "Here Is Information on Eutectic," which has just been published by the Eutectic Welding Alloys Corp., New York, contains factual and technical data about Eutectic "Low Temperature" Welding Rods* and Fluxes for torch and furnace and "LowTemp" EutecTrodes for arc welding.

This booklet gives specific applications where "Low Temperature" Welding Alloys can be used to good advantage, suggests which welding rod or electrode is best suited for the particular job, and lists complete technical information about the welding rod recommended, including bonding and remelting temperatures, Brinell hardness, strength, color match, etc.

* Trade-mark Reg. U. S. Pat. Off.

A copy of this publication may be secured by writing to the Eutectic Welding Alloys Corp., 40 Worth St., New York 13, N. Y.

MacKENZIE HONORED

Dr. James T. MacKenzie, chief metallurgist, American Cast Iron Pipe Co., Birmingham, Ala., will deliver the 1947 Charles Edgar Hoyt Annual Lecture at the fifty-first convention of the American Foundrymen's Association in Detroit, April 28–May 1, Sheldon V. Wood of Minneapolis, president of the technical society, has announced. Dr. MacKenzie has selected "The Cupola Furnace" as his subject.

Scheduled for the business session of the meeting, April 30, Dr. MacKenzie's presentation will inaugurate a new A.F.A. lectureship series established, by a renaming of the society's foundation lecture, to honor C. E. Hoyt for thirty years of "highly valued service to the Association and the foundry industry." Mr. Hoyt retired as A.F.A. treasurer August 1.

Internationally recognized as an outstanding foundry chemist and metallurgist, Dr. MacKenzie is particularly well known and has been frequently honored for his chemical researches, his many contributions to gray iron metallurgy and ferrous foundry practice, and his active participation in the work of technical and professional societies.

Dr. James T. MacKenzie

A member of A.F.A. since 1921, Dr. MacKenzie received the association's J. H. Whiting gold medal in 1937 "for important and highly practical work in the advancement of gray iron foundry practice." He has twice delivered A.F.A. exchange papers before the Institute of British Foundrymen, and in 1945 made a study of centrifugal casting methods in Germany

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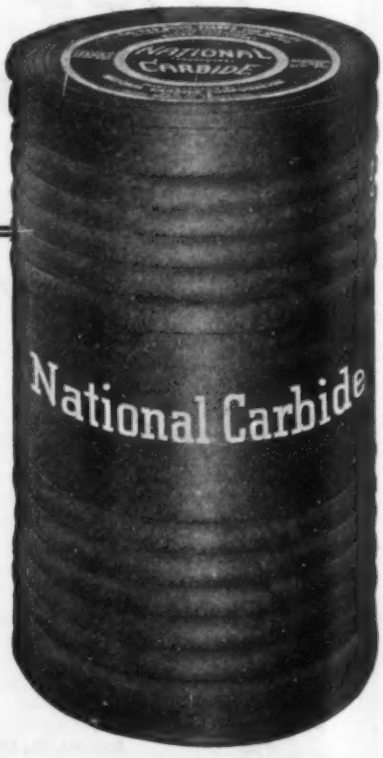

FOR WELDING and CUTTING

Use National Carbide in the Red Drum

Write us for information as to nearest available stock.

60 E. 42nd St. NATIONAL CARBIDE CORPORATION New York 17, N. Y.

Can you answer these questions about WELDING CAST IRON?

A TWO-MINUTE QUIZ OF INTEREST TO EVERY WELDER

Q. Is it harder to weld cast iron than steel or other metals?

A. Cast iron frequently proves more difficult to weld than other common metals. This is because of cast iron's tendency to change its structure under high heat.

Q. What is the effect of welding heat on cast iron?

A. Some of cast iron's useful properties depend on a proper balance between graphitic and combined carbon. When cast iron is reheated to the molten state, as in welding, some of the graphitic carbon recombines with iron to form combined carbon. Unless the iron cools gradually, the carbides thus formed remain as combined carbon. An excessive amount of combined carbon in cast iron makes the iron hard and extremely difficult to machine.

Q. How can this tendency be eliminated?

A. First, by avoiding excessive heat in the welding zone. Second, by obtaining a slow rate of cooling. Third, by choosing the right welding material.

Q. What is the best method of welding cast iron?

A. All have their advantages. For years, oxy-acetylene was the favorite. Now, however, because of recent improvements in electrode composition, the metal-arc method is coming rapidly to the fore.

Q. What are these improvements in electrode composition?

A. Research on electrodes for welding cast iron has centered around achieving strong, machinable welds, free from cracks and porosity. At INCO this has meant the careful study of the materials used for core wire and flux coatings in the development of the NI-ROD* electrode.

Q. Does NI-ROD provide sound, strong, welds?

A. Extensive use has proved the soundness of NI-ROD welds. NI-ROD's slag does an excellent job of scavenging gas from the weld metal, assuring deposits of maximum strength and freedom from porosity.

Q. Is preheating necessary with NI-ROD?

A. NI-ROD flows so well and "washes" so evenly against the sides of the joint that it is usually unnecessary to preheat the joint. However, hard-and-fast rules cannot be formulated to cover all conditions. Preheating to 300-400°F is useful on many jobs to reduce stresses or provide the highest degree of machinability.

Q. Are NI-ROD welds easily machinable?

A. Yes, NI-ROD's deposit and weld zone are easily machinable. The deposit is nickel, a metal which doesn't lose its machining characteristics under rapid temperature changes. The fusion zone retains its machinability because NI-ROD's smooth arcing and flow characteristics keep the heating-quenching cycle to a minimum.

•

NI-ROD comes in $\frac{3}{32}$", $\frac{1}{8}$", $\frac{5}{32}$" and $\frac{3}{16}$" diameters. Order a 5-lb. package and you'll agree it's the ideal answer to any cast iron welding problem where strong, sound, machinable joints are required.

*Reg. U. S. Pat. Off.

INCO NI-ROD TRADE MARK

Be sure to ask for your copy of the NI-ROD instruction booklet.

THE INTERNATIONAL NICKEL COMPANY, INC., 67 WALL STREET, NEW YORK 5, N. Y.

NI-ROD *is distributed by:*

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for the Federal Foreign Economic Administration.

He has a long record of A.F.A. committee service and has been particularly active as the association's representative on joint committees and on the ferrous metals group advisory to the National Bureau of Standards. He is currently a member of the advisory committee to the association's gray iron division.

Dr. MacKenzie has been equally prominent in the work of other technical and professional groups. In recognition of his service as a member of the American Chemical Society, he is nominee for national councilor-at-large of that organization. In a long association with the American Society for Testing Materials, he has served as a director and as chairman of its committee A-3 on cast iron.

A member of the American Institute of Mining and Metallurgical Engineers since 1924, he was chairman of its iron and steel division in 1938, national director in 1940–42, and Howe Memorial lecturer in 1944.

He is serving his third term as chairman of the electrothermic division, Electrochemical Society, and holds memberships in the American Society for Metals, American Ceramic Society, Society of Automotive Engineers, National Association of Corrosion Engineers, American Petroleum Institute, Society for Experimental Stress Analysis, American Gas Association, AMERICAN WELDING SOCIETY, Iron and Steel Institute of Great Britain, the Association Technique de Fonderie de France and others.

A native of Florida, Dr. MacKenzie was graduated from the University of the South in 1911 with a B.A. degree and in 1912 with B.C.E. and M.A. degrees. In 1930, in recognition of his "distinguished scholorship and outstanding scientific attainment" the university conferred upon him the honorary degree of doctor of science. In June 1946 he was elected a member of the university's board of trustees.

Dr. MacKenzie joined American Cast Iron Pipe Co. as an analyst in 1912 and later served as chief chemist and metallurgist until 1940, when he assumed his present position.

The association's annual lecture committee is headed by H. M. St. John of Crane Co., Chicago.

SEAM WELD IN TYPE 302 STAINLESS STEEL 0.0015 IN. THICK

Figure 1 is a macrophotograph (2 ×) showing the seam welding of Type 302 Stainless Steel in the 0.0015-in. thickness, as developed by Solar Aircraft Co., San Diego, Calif., for the fabrication of insulation blankets for a late type turbojet engine. The sample has been partially subjected to the peel test. Note that apex of the tear is well rounded and full width of the nugget, indicating complete fusion and a full strength weld.

The microphotograph (150 ×) shown in Fig. 2 is of a seam weld in this material made with identical procedure, except that welding speed is doubled in order to

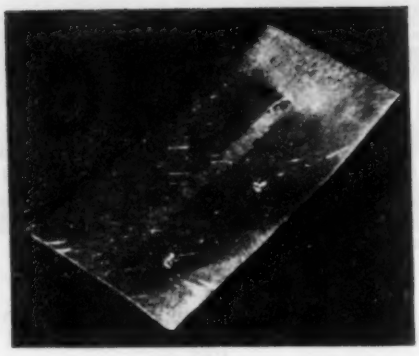


Fig. 1

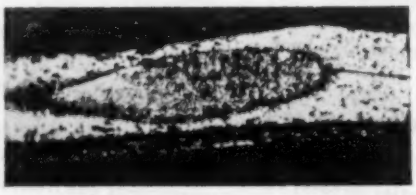


Fig. 2

expose individual nuggets for inspection. The diameter of the nugget shown is 0.011 in. along the major axis and 0.0023 in. on the minor axis. Weld penetration is approximately 72%. The nuggets show no evidence of voids, cracks, inclusions or abnormal structures.

Welding conditions are: electrode force, 120 lb.; time, 1 cycle on and 1 cycle off; current, approximately 4000 amp.; electrodes, RWMA Class 1, 8 in. diameter, $^3/_{16}$-in. wide, with $1^1/_2$-in. radius face; speed (for gas-tight welds), 18 in. per minute; spots per inch (for gas-tight welds), 100; material preparation, clean, free from grease or other foreign matter, free from finger prints. Light burnishing with No. 400 emery paper is recommended.

AIRCO ANNOUNCES NEW GENERAL WELDING AND CUTTING PRODUCTS CATALOG

The Air Reduction Sales Co. has announced publication of a new 64-page general welding and cutting products catalog. Profusely illustrated, this catalog is divided into two sections: one for oxy-acetylene welding and cutting gases, equipment and supplies; the other for arc welding machines, accessories and electrodes. The last ten pages of the catalog are devoted to specially compiled electrode price lists.

For a free copy of the useful, up-to-date catalog which includes prices, write to Air Reduction Sales Co., 60 East 42nd St., New York 17, N. Y.

GREAT INTEREST SHOWN IN LINCOLN FOUNDATION'S $200,000 DESIGN-FOR-PROGRESS AWARD PROGRAM

Inquiries from every state of the union and from 27 foreign nations indicate an unprecedented interest in the $200,000 Design-for-Progress Award Program sponsored by The James F. Lincoln Arc Welding Foundation of Cleveland, Ohio.

These inquiries, regarding the rules and regulations of the program, have been arriving daily since the program was announced in June of last year, and now number in tens of thousands.

This indicates the tremendous interest in welding stimulated in many cases by the remarkable part welding played in World War II. Many people who before had only a very casual interest were thrilled by the stories of the heroic adventures of welded ships, by the tales of unprecendented production, and savings in time and money made possible by this process.

Executives, engineers, architects, designers, professors, teachers, farmers, mechanics, aside from those following welding as a profession, comprise the majority of those inquiring of the program and this interest has been unequalled in past years.

The program, having the double purpose of stimulating scientific research and design involving arc welding and of making the results of these studies available generally, closes on June 1st of 1947.

The present program provides 452 awards totalling $200,000 for papers embracing every field of industry and research where arc welding may be applied, and in scope is comprised of 15 classifications and 43 divisions which have been established to permit wider participation for the entrants.

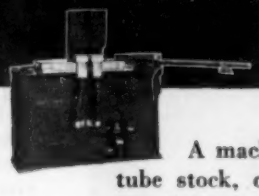
LOW TEMPERATURE JOINING

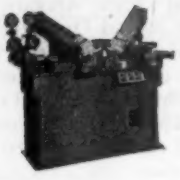
How you can save money by using low temperature for welding is the intriguing subject of a 32-page booklet now available upon request from All-State Welding Alloys Co., Inc., 96 West Post Road, White Plains, N.Y. This booklet not only tells about the savings resulting from the use of low-temperature welding, but also serves as a catalog and instruction guide for all of the products of the All-State line. These products include rods especially designed for work on cast iron, steel, stainless steel, copper, copper nickel, nickel bronze, and other copper-bearing alloys, zinc-base die castings, and aluminum; a glavanizing powder for cast iron, a powdered brazing compound and fluxes.

THE PLASTICITY, RUPTURE AND WELDABILITY OF METALS

A book entitled "New Methods of Study and Analysis of Metals and Their Application to Welded Constructions," has been prepared by Henri M. Schnadt, Engineer. This book consists of 250 pages, 60 figures, and is written in French. It covers such subjects as plastic deformations at a point, elasticity, plasticity and decohesion, constants of plasticity, aging of steels, weldability of ordinary and special steels and other related subjects. Henri M. Schnadt, 11, Ave. E. Ysaye, Bruxelles.

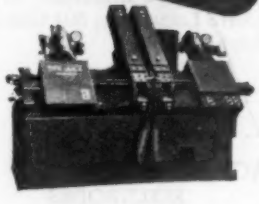
Sciaky Announces a Complete Line of *Advanced** Flash Welding Equipment

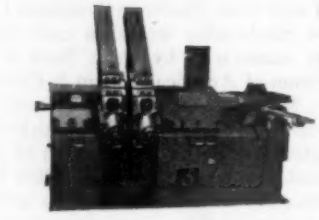


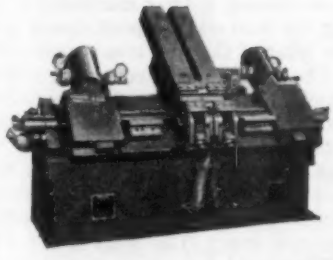


A machine for most every flash welding job—mitred sash, bar and tube stock, castings, etc.—is included in this series of *modern* welders. Revolutionary features in design and construction put these machines years ahead—in weld quality, flexibility and long life. Capacities range from .90 sq. in. cross sectional area on small hand-operated machines up to 5 sq. in. on large, completely automatic power-operated welders.

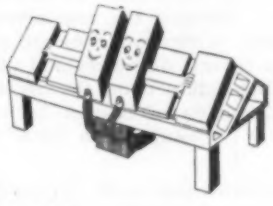
***and here's what we mean by Advanced**



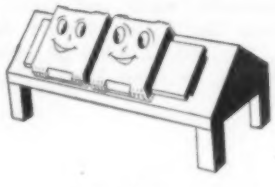




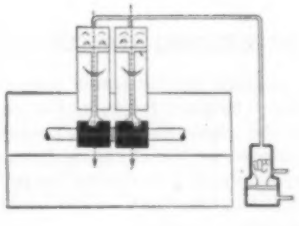
FRAMES are constructed as a sturdy, self-contained beam. Conductors from transformer to dies are placed *outside* the frame—eliminating need for weakening cutout and protecting transformer from flash sparks.



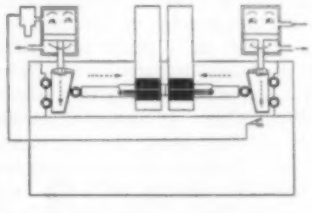
PLATENS move on a wide, rigid, T-shaped bed. Stresses are distributed over both upper and lower large, flat bearing surfaces. Accurate guiding is assured by narrow key. Tapered gibs maintain proper clearance.



CLAMPS are actuated by a booster-supplied high pressure hydraulic system. This allows cylinders of small diameter to be used which can apply force *directly in line* with clamps.



FLASHING and UPSETTING is controlled by air cylinders driving wedge-shaped cams between rollers. On power-operated welders, both platens move to allow independent control of flashing and upsetting. Heavy duty machines are equipped with two transformers—one connected to upper dies and the other to lower dies. Thus, perfect distribution of heat is assured on work such as large tubes.



SCIAKY

Ask for Bulletin 130-A

Informative 32-page booklet sent on request—write

SCIAKY BROS., INC., 4925 W. 67th St., CHICAGO 38, ILL.

NEW PRODUCTS

The Society assumes no responsibility for the validity of claims in this Section

AUTOMATIC ELECTRODES

The Wilson Welder and Metals Co., Inc., enters the field of automatic arc welding by announcing the addition of Una automatic wires and Una tapes to its line of manual electrodes. Five knurled type wires and five flux-impregnated tapes comprise the present line . . . all highly recommended for low cost yet uniform, automatic welding. Designed for flat position operation, their applications on the assembly line are many and varied, ranging from thin gage sheet metal forms to axle housings, boilers and torque tubes—to mention a few.

Subjected to continuous laboratory and field tests in order to assure highest quality results, Una automatic wires and tapes have been in constantly increasing demand since their introduction to industry. Meeting the requirements for high speed fabrication, they are now available in several diameters and alloy analyses. Depending upon the application, the automatic wires may be used separately or in conjunction with the tapes.

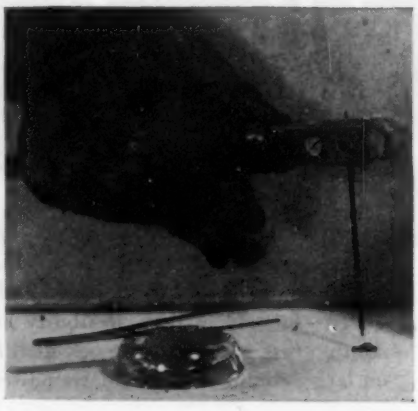
Further information on the Wilson line of Una automatic wires and tapes is available from the Wilson Welder and Metals Co., Inc., 60 E. 42nd St., New York 17, N. Y., or from local Wilson distributors.

ARC WELDING STARTER

An arc welding starter which does not require direct contact between the electrode and the work and which prevents overloads caused by the electrode freezing to the work is supplied in several forms by the Electrical Engineering Co., 355 Lemcke Bldg., Indianapolis, Indiana.

Illustrated is the maker's standard proof test. A tweezer-pinch of arc-starting powder is placed on a small test panel consisting of $1/4$-in. square by 0.020-in. thick cold-rolled steel, resting unclamped on the welding table. At a current setting of 15 amp. welding heat, the arc starts before a $1/16$-in. diameter electrode touches the surface of the test panel. The arc starter is applicable to all types of a.-c. and d.-c. welders, and is effective for both carbon and stainless steel.

It has been found particularly effective for striking an arc in restricted places and for making numerous short welds such as in jigged tack welding. The lessened nervous tension on the operator is noticeable when using this arc starter, regardless

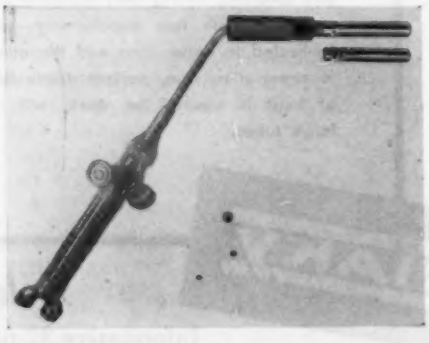


Arc Welding Starter—Standard Proof Test

of the amperage used. When low open-circuit voltages between 36 volts and 44 volts are required, this arc starter becomes even more effective, because the arc is initiated during the approach movement of the electrode. Hence, the usual difficulty of breaking the arc of the initial bounce or scratch strike—caused by the electrode tip being inadvertently withdrawn beyond sustaining-arc distance—is not encountered by the operator.

SOLDERING TORCH

A handy new accessory which affords double-duty for all oxyacetylene welding torches has been announced by Cesco Products, Inc. Known as the Cesco Puddler, this new unit fits over the end of any standard welding torch tip. It is used with acetylene alone and provides an ideal flame for body soldering, tinning, silver soldering and heating jobs. Two tips are furnished with the kit. One for light duty soldering and one for body soldering. Complete information can be obtained from Cesco Products, Inc., 30 N. LaSalle St., Chicago 2, Ill. Ask for Bulletin No. 12.



Cesco Puddler Adapts Welding Torches for Soldering, Tinning and Heating Jobs

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OXYARC PROCESS FOR CUTTING STAINLESS AND ALLOY STEELS

Arcos Corp. has developed a new method for hand cutting or piercing stainless and stainless clad, alloy steel, aluminum, bronzes and brasses, cast iron, Monel, Inconel and nickel. The process—known as the Arcos Oxyarc Process—achieves the cutting by the combination of an electric arc and a stream of oxygen.

The equipment consists of a specially designed Arcos Oxyarc holder, and a tubular coated Oxycuttend rod which is consumed in the process of cutting. The process can be used wherever an a.-c. or d.-c. welder and bottled oxygen are available. The "knack" of cutting with Oxycuttend can be acquired in less than an hour's time.

Because the Oxyarc Process will cut or pierce any metal, in any shape, and in any position, it can be used to great advantage in a wide variety of metal cutting operations. The equipment used in the Oxyarc Process is low cost and represents one of the most versatile and effective hand tools ever devised for cutting metals—particularly stainless and nonferrous metals.

For descriptive literature write Arcos Corp., 1515 Locust St., 504 Gulf Building, Philadelphia 2, Pa.

PAGE NI-CAST SHIELDED ARC ELECTRODES

A new Page electrode developed to produce machinable welds on cast iron has been announced by Page Steel & Wire Division of American Chain & Cable Co., Inc., Monessen, Pa. The soft weld metal deposited by Page Ni-Cast Shielded Arc Electrodes bonds perfectly with all grades of cast iron, making it unexcelled for repairing broken or worn castings and casting defects, and for correcting errors made in machining. After machining or grinding, the weld metal deposit closely matches the color of the cast iron parent metal.

The special nickel core wire, which has a nickel content of over 99%, has a coating which is free of fluorides and other ingredients which generate injurious gases. Page Ni-Cast Shielded Arc Electrodes have a very quiet stable arc free from spatter with a minimum of penetration and heating of the cast iron. The weld metal deposit will be sound, homogeneous and free from porosity on all grades of cast iron while the fusion zone of the casting will be free from hard zones of white iron.

Page Ni-Cast Shielded Arc Electrodes can be used with alternating current or with either polarity direct current. It is manufactured in $3/32$, $1/8$, $5/32$ and $3/16$ in. diameters and is packed in 10-lb. cartons.

Advantages

OF LUKENS STAINLESS-CLAD STEELS

★ **Corrosion resistance and product protection of solid stainless steel, at appreciable savings in cost over solid stainless.**

★ **Any standard specification stainless cladding, including straight chromium types 410 and 430 and chromium-nickel types 304, 316 and 347.**

★ **Uniform thickness of cladding.**

★ **10% or 20% clad usually furnished, but any percentage from 5% to 50% obtainable.**

★ **Any quality carbon or alloy steel backing plate depending on the requirements.**

★ **Heat conductivity far superior to solid stainless. Better heat transfer properties provided by the complete bonding of the stainless cladding with the steel backing plate.**

★ **Readily fabricated.**

★ **Plates from 3/16" to over 3" thick, or up to 162" wide. It is always cheapest to fabricate the widest plate suitable.**

★ **Flanged and dished heads of all styles and sizes to over 18' in diameter. Lukens has specialized in forming heads for over 55 years.**

Additional information on Lukens Stainless-Clad Steels is offered in the new Bulletin 338; on other Lukens Clad Steels, in Bulletin 255.

LUKENS

Nickel-Clad Stainless-Clad
Inconel-Clad Monel-Clad
STEELS
★

LUKENS STEEL COMPANY

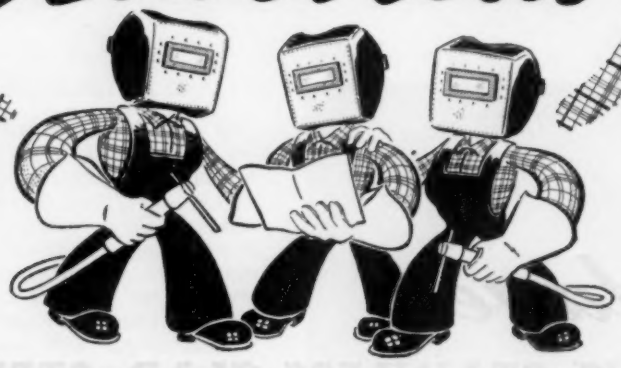
World's Largest Plate Mill

357 Lukens Building ★ Coatesville, Pa.

Cable Address: Lukens

MARQUETTE

Instant arc
A.C. WELDERS
3 Lower Costs



LOW INITIAL COST Marquette "Instant Arc" A.C. Welders are built for heavy-duty 'round the clock production welding. Special transformer design gives you "Instant Arc Striking" and the exclusive A.C. feature of "Balanced Polarity" which completely eliminates all troublesome "Magnetic Blow". Marquette "Instant Arc" A.C. Welders cost less than motor driven machines of comparable output.

LOW MAINTENANCE COST Nothing to wear out because Marquette "Instant Arc" A.C. Welders have no moving parts to wear out . . . no motors, no generators, no brushes, no bearings and no moving cores or coils. Nothing to get out of order, no confusing charts or dials to adjust.

LOW OPERATION COST Models 262 C and 261 C have Built-In Capacitor for High Power Factor (for lower power company rates) Power costs: Marquette Welders will make a butt weld two feet in length for only 1 cent compared to 3 cents for D.C. machines and 32 cents for oxy-acetylene welding.

Marquette Welders are economical Three Ways . . . Low Initial Cost, Low Maintenance Cost, and Low Operating Cost. Welding is the shortcut to faster production and lower costs. Ideal for all maintenance and repair jobs. Models: 262 and 262C (with capacitor) 20–275 amps., 261 and 261C (with capacitor) 20–200 amps. Eight additional models, 125 to 400 amps.

Write for Literature
Sold Exclusively thru the Nation's Leading Distributors

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Welding
EQUIPMENT
A.C. ARC WELDERS · ELECTRODES
GAS WELDING And CUTTING EQUIPMENT
ACETYLENE GENERATORS · ACCESSORIES

MARQUETTE MFG. CO., INC.
MINNEAPOLIS 14, MINN.

For complete information drop a card to Page Steel & Wire Division, American Chain & Cable Co., Inc., Monessen, Pa.

NEW G-E GAGE MEASURES THICKNESS OF PIPES FROM OUTSIDE

A new thickness gage designed to measure the thickness of iron or steel pipes from the outside has been announced by the Special Products Division of the General Electric Company. Called a pipe thickness gage, Type MS-A, the new instrument can be used on pipes up to 1/4 in. in thickness and from 1 to 2 in. in diameter. Applications include checking the safety factor of pipes and tubing carrying petroleum products, chemicals, steam or gas.

Thickness Gage, Type MS-A, Being Used to Check Pipe Thickness

The new thickness gage consists of an indicating instrument, a gage head, and a saddle which is connected to the gage head by two screws. A different saddle is required for each diameter of pipe. To operate, the saddle is placed upon the pipe, and thickness is indicated in fractions of an inch on the indicating instrument.

The gage measures the average thickness of a pipe over an area of several square inches. Accuracy of plus or minus 1/64 in. can be obtained on clean surfaces, and 1/32 in. on dirty surfaces. Dirt, scale and paint on the inside of a pipe do not add to the thickness reading. The gage head and saddle combination weighs about 6 1/2 lb. The instrument operates on 115-volt, 60-cycle power.

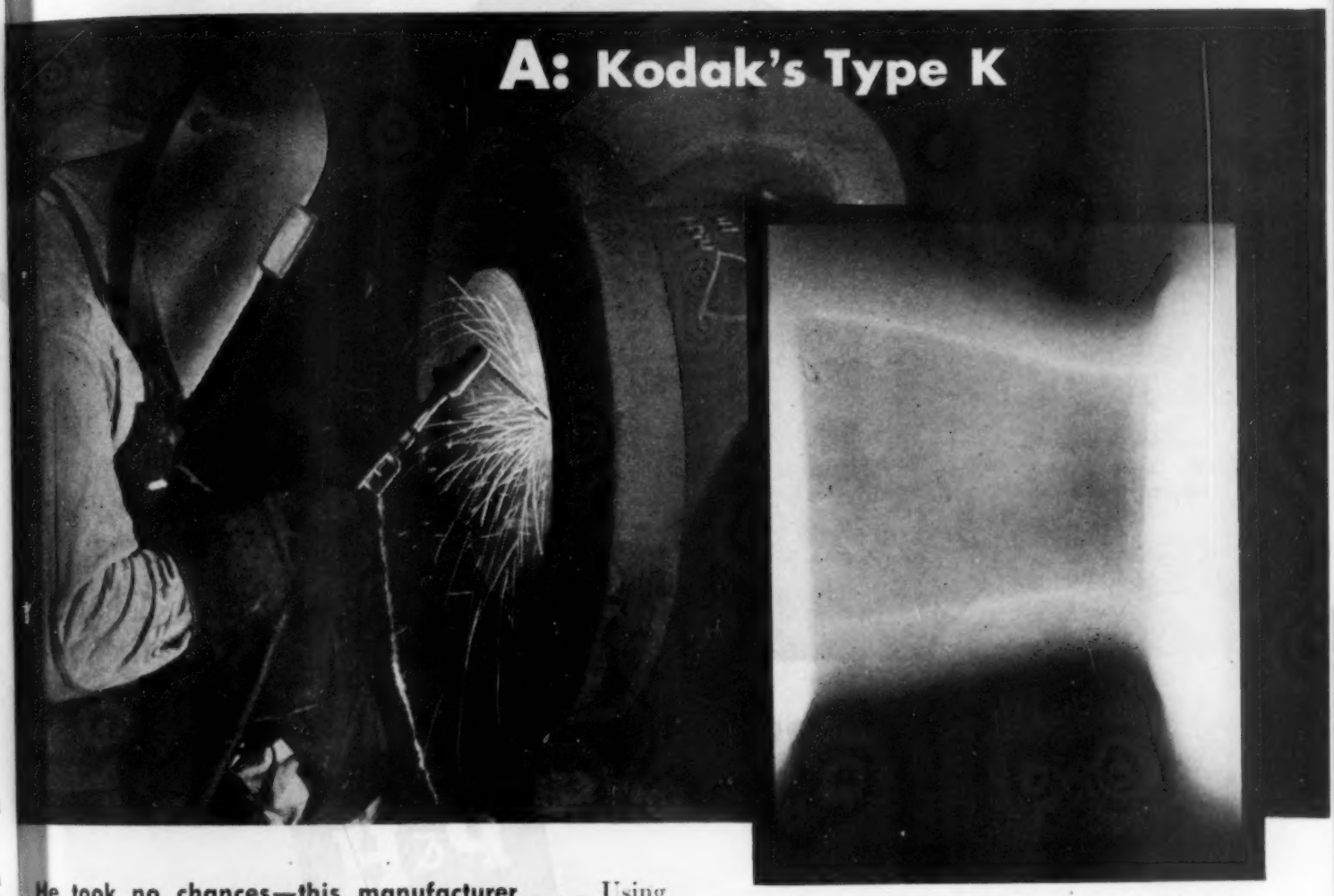
RUB-ON SOLDER

All-State Welding Alloys Co., Inc., 96 West Post Road, White Plains, N. Y., announces the immediate availability in unlimited quantities of a still lower-temperature rub-on solder that opens up a new range of soldering applications for aluminum work. This addition to the All-State line of low-temperature welding and brazing alloys is an amazingly economical alloy that is applied without flux.

Prime applications of this alloy are de-

Q. Which film is first choice for fast gamma-ray inspection of this repair weld?

A: Kodak's Type K



Internal appearance of casting in area of weld repair.

He took no chances—this manufacturer . . . Using radiography, he found that this cast-steel elbow was imperfect, but that it could be repaired. Then he determined the soundness of the repair weld by using radiography again.

What film did he use? . . . Kodak Industrial X-ray Film, Type K, of course. Why? Because Kodak's Type K . . . the fastest of all gamma and x-ray films . . . enabled him, in the shortest possible time, to see the internal structure of this heavy casting with sufficient detail.

Radiography more than pays its way . . . In welding operations, radiography shows the welder step by step that his work is sound and thorough . . . preventing failure or customer rejection. For more information about the production efficiencies and economies that x-rays make possible, see your local x-ray dealer, or write . . .

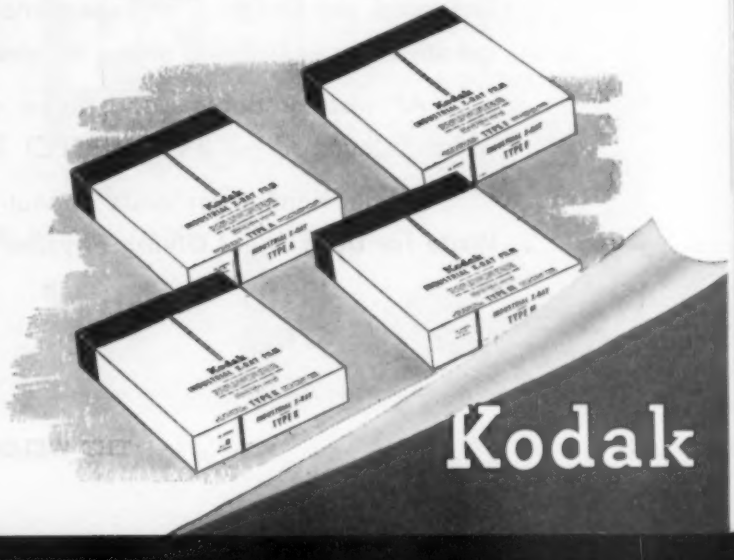
EASTMAN KODAK COMPANY
X-ray Division, Rochester 4, N. Y.

Other Kodak Industrial X-ray Films

Type A . . . for gamma-ray work in sections where finer film grain and higher contrast are desirable for maximum sensitivity at moderate exposure times.

Type F . . . for use with calcium tungstate screens. Primarily for x-raying heavy steel parts, where only moderate voltage x-ray equipment is available. Radiography at its fastest!

Type M . . . first choice in critical inspection of light alloys or in the examination of thin steel at moderate voltages and heavy alloy parts with million-volt equipment.



Radiography

. . . another important function of photography

SPEED UP out-of-position welds with 3/16"...

P&H

"AP"

CLASS AWS-ASTM-E6010

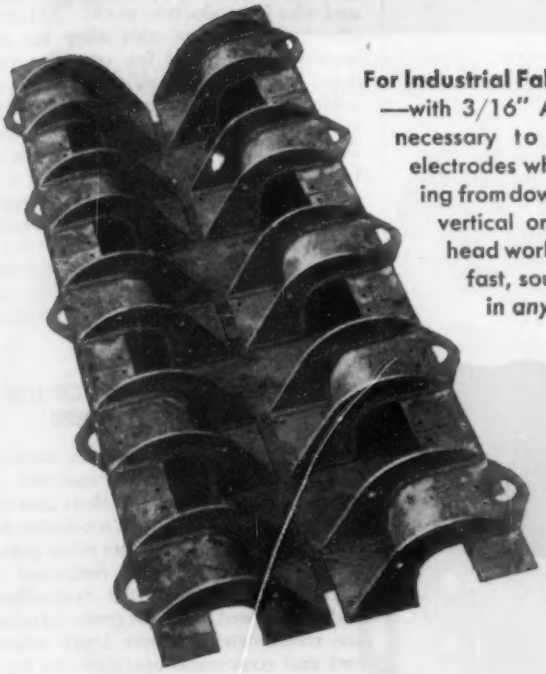
Because of its remarkable versatility, you can use AP size 3/16" in place of 5/32" on all types of joints—in all positions.

AP is easier to handle . . . it has a fine SPRAY-TYPE ARC. Its DEEP PENETRATION qualities assure strong, lasting bonds and produce X-RAY PERFECT welds. Its unusually LOW SPATTER LOSS means extra footage, increased production. Its exceptionally THIN, EASILY REMOVED SLAG greatly reduces cleaning time. AP gives you all these cost-lowering advantages.

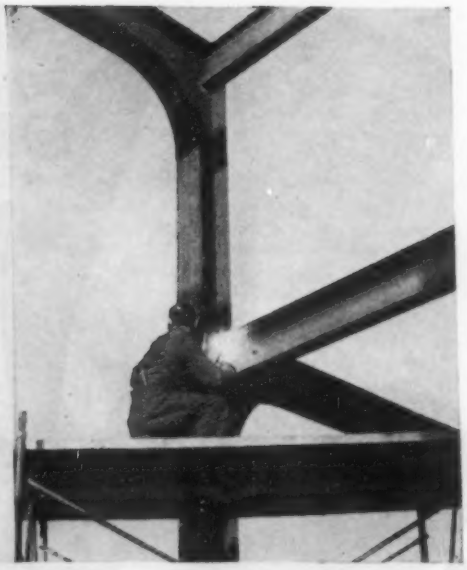
AP also produces good tie-ins and fast, spot penetration without "humps" — it's a PERFECT TACKING ELECTRODE.

If you want lower costs on out-of-position welds, use AP.

Write for Data Sheet Giving Physical Properties, Applications and Procedures



For Industrial Fabrication —with 3/16" AP it isn't necessary to change electrodes when welding from downhand to vertical or to overhead work. You get fast, sound welds in *any* position.



On Construction Work — AP, in this one size, welds in all-positions. It means far fewer electrode changes . . . fewer danger-making moves. You can weld faster, and get better welding.

For Tack Welding — AP is the perfect electrode. It eliminates "hump" troubles with deep, flat, spot penetrations.

For Pipe Welding — 3/16" AP saves time and space over other fabrication methods. Use it for pipe, fitting and boiler work — profit by its deep-penetrating, spray-type arc, its smooth, fast welds.

Your P&H REPRESENTATIVE has AP

P&H makes a production-proved electrode for every welding requirement: for all mild, alloy and stainless steel applications, cast iron and for building up and hard surfacing.

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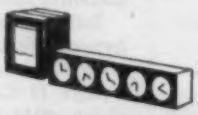
HARNISCHFEGER CORPORATION

AMERICA'S MOST COMPLETE ARC WELDING SERVICE.

WELDING POSITIONERS


WELDING PRODUCTION CONTROL SYSTEMS

ELECTRIC HOISTS

DC WELDERS

AC WELDERS

WELDING ELECTRODES

Doubling in Brass

Phos-Trode

Shielded-Arc Phosphor Bronze Electrodes

do two jobs — provide an excellent bond with brass, and an excellent deposit for resistance to salt water corrosion

Defective material in the old key-way was chipped out. Then, the entire area was filled in, flush with the inside bore, with Phos-trode weld metal. The dense Phos-trode deposit was easily machined to proper size.

The finished job: A new key-way was cut opposite the welded repair, and the huge brass casting was saved.

Salvaging this giant brass naval propeller with Phos-trode represents a saving of many thousands of dollars.

Phos-trode is Ampco's new Phosphor Bronze Electrode. It is becoming increasingly popular throughout industry — not only because it is ideal for welding cast iron, steel, bronze, or brass, but also because it often eliminates the need for large capital expenditures by permitting satisfactory repairs instead of costly replacements.

Phos-trode is easy to manipulate in all positions; its dense, pit-free deposits require less peening; its higher deposition rates, its greater efficiency, and its reduction of operator fatigue result in over-all economy. Get all the facts from your nearest Ampco weldrod distributor.

Write for latest bulletins.

AMPCO

Phos-trode is a product of AMPCO METAL, INC.

AMPCO METAL, INC.

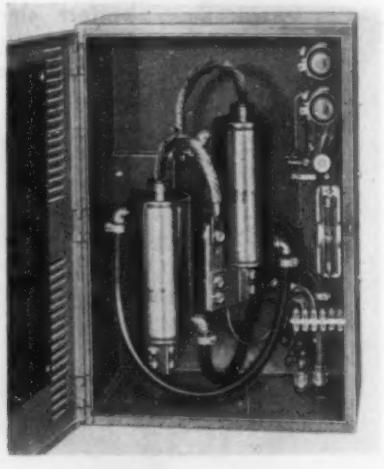
Department WJ-2 Milwaukee 4, Wisconsin

W-96

veloping rapidly among companies requiring the assembly of aluminum shapes and wire in production work. As used on aluminum castings, this alloy has good matching color and fair corrosion resistance. It is recommended for filling and soldering where tightness is essential but strength is unimportant, for the repair of blowholes, and for building up worn surfaces on aluminum castings as well as for salvaging and making changes on foundry patterns. It is also excellent for repairing cracks in aluminum cylinder heads and for filling in surface defects where high temperatures must be avoided. This alloy is known as All-State No. 39 aluminum solder rod.

ELECTRONIC CONTACTOR FOR RESISTANCE WELDERS

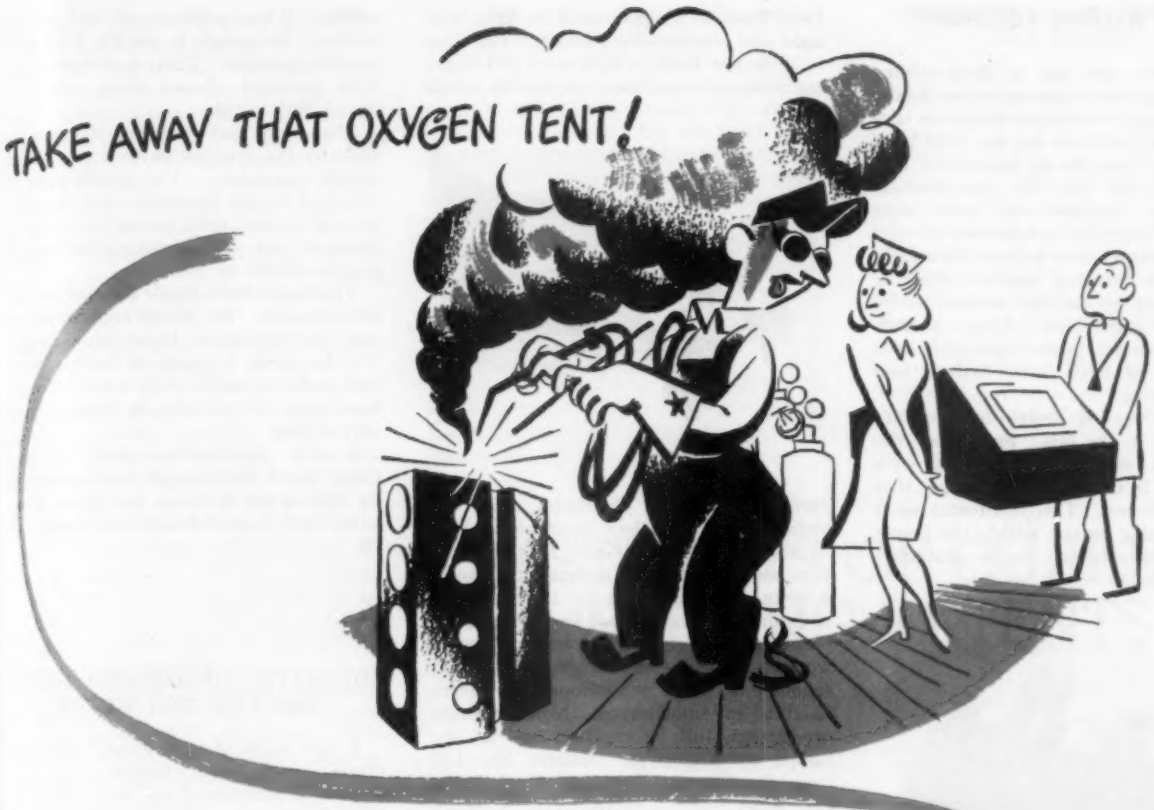
For resistance welding jobs involving exceptionally high-speed operation or heavy primary currents of short time duration, Square D Co. offers a complete new line of electronic contactors using ignitron tubes. These electronic contactors are offered to supplement the Syncro-Break and High Speed magnetic contactors which are recommended where lower installed cost and economical operation are important factors and where welders must operate over a wide range of weld times and duty cycles.



Design of the new Class 8990 electronic contactors provides increased wiring space with power connections made near the center of the enclosure allowing minimum bending of power cables. The contactor is assembled on a removable steel base plate. All control elements are grouped at the right-hand side away from tubes and cables and out of the path of any dripping from water condensation on tubes and hoses.

Cabinets are heavy sheet steel with ventilating louvres in the door and drain holes in the bottom. Flat door construction is used to permit close ganging of contactors and provide maximum utilization of space.

Bulletin 8990 describing Electronic, Syncro-Break and High Speed welder contactors can be obtained by writing Square D Co., Industrial Controller Division, 4041 North Richards St., Milwaukee 12, Wis.



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REVERE NO. 456 LOW FUMING

BRONZE WELDING ROD

A WELDER can work in comfort with Revere No. 456 *Low Fuming* "Flame Tested" Welding Rod . . . and produce finished welds with higher strength in the weld metal. In the straight fusion welding of cast iron, Revere No. 456 saves time and fuel. And gives you strong, sound joints in the bronze welding of cast and malleable irons, wrought iron, cast and wrought steel, cast and wrought bronze.

Other Revere welding rods are: Revere Bronze 380, Manganese Bronze, Herculoy, Phosphor Bronzes, Brass (Brazing Rod), Silicon Deoxidized Copper, Phosphor Deoxidized Copper, Electrolytic Copper. They are handled by Revere Welding Rod Distributors in all parts of the country. Write for folder giving technical data and net prices.

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• • •

Listen to *Exploring the Unknown* on the Mutual Network every Sunday evening, 9 to 9:30 p. m., EST.

FLASH WELDING EQUIPMENT

A complete new line of flash-welding equipment has been announced by Sciaky Bros., Chicago. Welders range in size from 75-kva. for 0.90 sq. in. mild steel up to large, completely automatic machines rated 500 kva. for capacities up to 5 sq. in. Included are mitre joint welders for improved production of steel and aluminum window frames, door sash, etc., for the building trades. Flashing and upsetting on smaller welders is by means of a hand lever. Large welders may be either all power operated, or a combination of hand lever flashing and power upsetting.

Several advanced design features are incorporated in the line. *Frames* are designed as a self-contained beam with conductors from transformer to dies *outside* the frame. This eliminates need for a weakening cutout within the frame and allows transformer to be protected from flash sparks.

Platens move on a wide, rigid, T-shaped bed with a narrow guiding key. Accurate guiding is assured with stresses distributed over large flat bearing surfaces.

Clamps are actuated by a high-pressure, booster-supplied hydraulic system. This allows the use of small diameter cylinders so that the direction of force can be directly over the clamps.

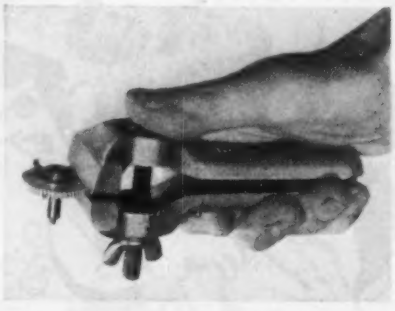
On the large power-operated machines, *flashing* and *upsetting* are independently controlled. *Both* platens are moved by an air cylinder driving a wedge-shaped cam between rollers. These can be controlled so that it is seldom necessary to change cams.

When welding tubes over 3 in. O.D. a dual transformer supplies heat to *both* upper and lower dies, assuring perfect distribution of heat.

Heavy duty machines can be equipped with synchronous timing control, post-heat current and phase shift heat control to permit welding of aluminum alloys, high carbon and aircraft steels.

NEW HAND VISE HOLDS SMALL PIECES TIGHTLY

To make handling of small parts and pieces easier and safer for both bench and production jobs, the Chicago Tool and Engineering Co. has introduced a new aluminum hand vise which grips solidly, yet will not mar or scratch the work. Only 7 oz. in weight and 5 in. long, it is light and comfortable to hold. The $1^1/_2$-in. wide jaw faces, which open to $1^1/_2$ in., are accurately machined to provide a true



surface. Made of aluminum, they are sufficiently softer than most pieces held to provide a "Velvet Grip" that prevents the jaws "biting" or marring the work. Known as the Palmgren No. 15 Hand Vise, it is ideal for use by tool and die makers, manufacturing jewelers, metal and wood workers, machine manufacturers, repair, school and home workshops and others handling any small pieces. Now in volume production, full information can be obtained by asking for Bulletin No. 150 from the Chicago Tool and Engineering Co., 8383 South Chicago Ave., Chicago 17, Ill.

SPEED-SHIFT GOGGLE

One of the problems encountered by welders has been solved by the introduction of a new speed-shift goggle mounted on a comfortable plastic headgear. Development of this goggle has been announced by the Chicago Eye Shield Co.

Welders must constantly shift goggles from their eyes to their forehead for layout and inspection. With ordinary goggle this frequently is a two-handed job, and means the welder must lay down his tools to re-position his goggles. With the new Cesco Speed-Shift, a quick flip of one hand moves the goggles in and out of position. The welder simply pulls the goggles slightly forward, then releases them on the forehead. The whole process takes but a second. When inspection of work has been finished, the goggle is quickly returned to working position. There is no interference with personal glasses worn under the Speed-Shift goggle.

This speed and efficiency is made possible by the application of a new idea in goggle suspension. The goggle cups are attached to the headgear, and controlled by coil springs, mild enough to eliminate pressure, yet strong enough to hold the goggles firmly in place.

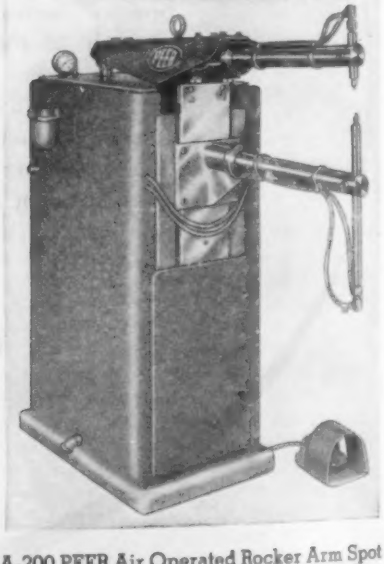
The Speed-Shift goggle offers other comfort features. The goggle cups are adjustable to individual facial requirements. The headgear is made of flexible, form-fitting plastic, and is easily adjusted to any head size. It can also be cleaned easily with a cloth.

Further information about the new Cesco Speed-Shift goggle can be obtained by writing the Chicago Eye Shield Company, 2300 Warren Boulevard, Chicago 12, Ill.

AUTOMATIC AIR-OPERATED ROCKER ARM TYPE SPOT WELDER

A new series of high speed, fully automatic air-operated, rocker arm, spot welders is announced by Pier Equipment Manufacturing Company of Benton Harbor, Michigan.

These new Series A-200 welders incorporate a double acting air cylinder of ample size to provide the high electrode pressure essential for consistent high production of quality welds. The rocker arm is mounted on roller bearings for long life under severe operating conditions, and hammering of the electrodes is minimized by the light weight welded steel construction of the rocker arm assembly. Minimum obstruction on the front of the welder and around the rocker arm assembly facilitates the handling of large or irregular shaped parts, and a highly efficient elec-



A-200 PEER Air Operated Rocker Arm Spot Welder Mf'd by Pier Equipment Mfg. Co., Benton Harbor, Mich.

trical design provides a lower power demand for a given welding job.

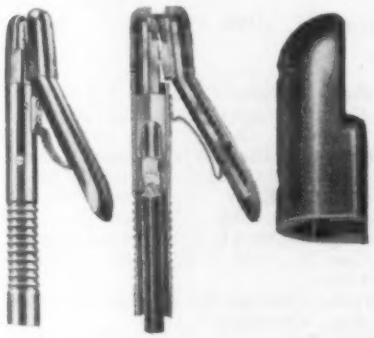
Standard equipment includes foot switch control, air pressure regulator, universal horns, water-cooled electrode holders and one set each of straight and offset copper alloy welding points. Series A-200 Peer Welder capacities are 10 and 15 kva. with throat depths of 8, 12, 18, 24, and 30 in. For further details write Pier Equipment Mfg. Co., Benton Harbor, Mich.

"LITTLE DAVID" IS A NEW ELECTRODE HOLDER

Substantial decrease in temperature operation, making possible greater efficiency and service economy, is gained with use of the Little David, a new, lightweight, tong-type electrode holder now on the market.

While some holders will show an increase of as much as 500° F., the Little David, rated at 350 amp. for rods up to and including 1/4 in. in diameter, operates with a rise in temperature of only 50° F., laboratory tests have shown.

A combination of design and material is responsible for lower temperature operation, manufacturers explained. The Little David is made of copper-bearing aluminum alloy of the type generally used for aircraft production. It is an alloy combining lightness with strength. A key-hinged fulcrum makes possible maximum conductivity.



Additional advantages of the new holder, manufacturers pointed out, are its slip-on insulating covers, over-all insulation protecting both operator and equipment, and easy, on-the-job maintenance because of Allen head screws.

The same slip-on insulating cover is used on either the top jaw or bottom jaw. Stock-keeping on cover replacements, therefore, is cut in half. Both tong and reversible slip-on jaw covers are of the domed, ventilated type which provides more effective heat dissipation.

For maximum current capacity, contact points on the jaws are extruded from 99.9% pure hard copper.

A soldered cable terminal is quickly released without removing the handle. A turn of an Allen screw head does the job. With only a 0.001 tolerance between the cable terminal and receptacle, an efficient electrical connection is assured.

Operator fatigue is materially reduced, designers of the tool observed, because of a perfect balance and light weight. Weighing only 12 oz., the Little David is one-third lighter than other insulated tong-type holders of the same rating.

Making it easy for welders to open the Little David jaws, the spring and lever ratio is scientifically designed to provide greater leverage. A fully insulated single leaf spring eliminates cups and coils.

The Allen Wrench, the only tool needed to service the Little David, is contained inside the lower tong insulating cover when not in use. Covers will slip off without so much as a turn of a crew, but with the wrench the entire holder can be taken apart and reassembled in a few minutes. No screwdriver or other tool is needed.

A descriptive folder illustrating the Little David and its features can be obtained from The Lacey-Webber Co., Kalamazoo, Mich.

"WHO'S WHO IN ENGINEERING," 6TH EDITION

Engineers throughout the country will soon receive material, questionnaires and previously printed records, bearing on the new (6th) edition of "Who's Who in Engineering." This work is being revised under the editorship of Dr. W. S. Downs, with qualifications established by a committee of the Engineers Joint Council.

The importance to the profession of an officially-guided work of this nature, and the desirability of the cooperation and support of the individual engineer, cannot be over-emphasized. The editor and the publishers are well-known to engineers through previous editions of this widely-used reference work.

ABSTRACTS OF CURRENT WELDING PATENTS

Prepared by V. L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington 10, D. C.

2,411,652—WELDING TOOL—Joseph U. Garibay, inventor, Montebello, Calif. (2 Claims)

Garibay's patented tool comprises an electrode holder having a pair of cooperating jaws for supporting a welding rod, which jaws have individual insulating covers thereon, and having an insulated handle portion.

2,411,737—METHOD AND APPARATUS FOR CONTROLLING TORCH SPACING—Henry O. Klinke, inventor, Forest Hills, N. Y., assignor to Air Reduction Co., Inc. (8 Claims)

In this control apparatus, means are provided for moving the torch tip toward and away from the work surface and the torch tip carries liquid jet-producing means adapted to produce two fine jets of a conductive liquid at an angle toward the work surface and toward the torch flame so that one jet is higher than the other. Electric circuits connect the flame jets to the torch tip positioning means so that when the torch flame interrupts only the upper jet, no movement occurs but when the flame interrupts both or neither jets, corrective positioning action of the torch tip is effected.

2,411,859—WELDING ELECTRODE CONSTRUCTION—Ralph R. Harwood, inventor, Detroit, Mich. (5 Claims)

Harwood's electrode is made of soft material, such as copper, and it has a reinforcing collar of greater resistance to deformation. The collar is at the electrode tip and open at the operating tip to enable the copper electrode to contact the work.

2,411,921—WELDING TRANSFORMER—Harry E. Kennedy, inventor, Berkeley, Calif., assignor to The Linde Air Products Co. (6 Claims)

The transformer has a core, a fixed coil, a movable coil and a pressure-responsive actuating device associated with the movable coil for moving it. The magnetic repulsion between the coils and the pressure applied by the actuating device solely control the movable coil's position.

2,411,920—ELECTRODE HOLDER—Clarence Ringwall, inventor, Springfield, Ohio. (20 Claims)

This novel holder includes a main member having a clamp jaw at one end and a clamp jaw pivotally mounted on the member. An insulator housing encloses the clamp jaws and provides a limit stop for a weld rod engaged thereby.

2,412,022—WELDING DEVICE—Glenn M. Whitmore, inventor, Oakland, Calif. (8 Claims)

The patented device is an electrode holder which has a hollow body in the form of a hollow coil connected to a welding circuit, and a core positioned longitudinally in the magnetic field in the coil. A member is provided for clamping the core against a welding electrode.

2,412,044—WELDING PRESSURE CONTROLLING APPARATUS—Hans H. Hansen, inventor, Warren, Ohio, assignor to The Taylor-Winfield Corp. (5 Claims)

The pressure control disclosed relates to electric resistance welding and it provides a movable member for applying welding pressure. The member is connected to two opposed, variable pressure chambers with the resultant of the two pressures in the chambers being applied as the welding pressure.

2,412,065—ELECTRIC WELDING WITH PORTABLE FLUX BOX—John Edward

Rudy and John Joseph Zaleski, inventors, Coatesville, Pa. (11 Claims)

A welding method is covered in this patent and it is for use in welding metal joints wherein the metal is chamfered on both sides. Flux is pressed into and retained in the groove provided by one chamfer, this chamfer is turned to face downwardly, and the then upper chamfer is welded. The weld is completed by righting the joint and welding the metal defining the chamfer groove which now is facing upwardly.

2,412,067—Control of Flash Welding—Clyde E. Smith, inventor, Warren, Ohio, assignor to The Taylor-Winfield Corp. (12 Claims)

Smith's control is for flash welding apparatus having relatively movable platens and an electrical circuit connected to carry current to work pieces held in the platens. The control has a timer and means to start the timer on completion of a flashing period and substantially at the time of movement of the work pieces into engagement at the start of their upsetting. The timer controls means for interrupting the weld circuit.

2,412,069—Driving Means for Roller Electrodes and the Like—Willibald Trinks, inventor, Pittsburgh, Pa., assignor to The Taylor-Winfield Corp. (10 Claims)

Trinks' patent relates to electric resistance seam welding apparatus having a pair of roller welding electrodes adapted to engage the work simultaneously. The electrodes are individually driven and a torque responsive device is in each of the drive circuits and it connects to and controls means for regulating the speed ratio between the driving means for the electrodes.

2,412,080—Welding Apparatus—Robert C. Cunningham, inventor, San Francisco, Calif. (8 Claims)

The patented apparatus has an electrode in a d.-c. welding circuit which is broken by an electroresponsive circuit breaker which is controlled by a second circuit breaker that is controlled by a timer. A starting circuit of momentary duration connects through the electrode to the timer.

2,412,166—Machine for Electric Welding Can Bodies—Ralph M. Mero and Alfred Treff, inventors, Chicago, Ill., assignors to Continental Can Co., Inc. (7 Claims)

In this patent, a special machine for supporting and spot welding the lap portions of the side seam of a can body is disclosed.

2,412,175—Spot Welding—Edmund T. Ridgway, inventor, Oaklyn, N. J., assignor to The Budd Co. (2 Claims)

The spot welding method of the patent includes forming an enclosing bead in one member, simultaneously compressing the material surrounding the bead and producing a weld in the central portion only of the region surrounded by the bead so that the compressive forces around the weld are substantially neutralized.

2,412,309—Insulated Electrode Holder—Martin Wells, inventor, Los Angeles, Calif. (11 Claims)

Well's holder has a metal body with a locking shoulder thereon, and a tubular insulator received on the body and having a resilient finger for engaging with the locking shoulder.

2,412,492—Welding Electrode Holder—Edward Brazitis, inventor, St. Clair Shores, Mich. (12 Claims)

This electrode holder uses a bushing made of electrical insulating material as part of the fastening means to secure the holder together.

2,412,660—Gravity-Feed Arc-Welding Apparatus—Joseph M. Tryner, inventor, New York, N. Y., assignor to Air Reduction Co., Inc. (7 Claims)

The gravity-feed arc-weld apparatus comprises a triangular shape frame having a guide part and a slide part with the slide part carrying a welding rod holder that slides down the slide part by gravity. The guide part has a pair of spaced parallel rods that are adjustably positioned to enable the apparatus to accommodate different size weld rods. A welding rod carried by the welding rod holder extends between the parallel rods to be positioned thereby.

2,412,717—Electrode Holder—John E. Cotton, inventor, Batesville, Miss. (4 Claims)

This holder has metal jaws which are connected through a member having a roller bearing on one jaw which has a resilient connector section and a rigid end section that is parallel to the other metal jaw.

2,412,745—Welding System—David Packard, Palo Alto, and Noel E. Porter, Berkeley, Calif., inventors and assignors to Hewlett-Packard Co. (4 Claims)

The patented welding system is of the type having a motor connected to a.-c. supply lines through a starter switch and a d.-c. generator is driven by the motor and connected to an arc welding circuit. Electrical controls are provided for the system and they include a totalizer, and means for energizing the totalizer only during normal arc welding operations and for deenergizing the totalizer on interruption or short circuit of the welding circuit.

List of New Members

December 1 to December 31, 1946

BOSTON

Puffer, Daniel W. (C), General Electric Co., Bldg. 76, 920 Western Ave., W. Lynn, Mass.
Wilson, George F. (C), 93 Aster Circle, Weymouth, Mass.

BRIDGEPORT

Olson, Arthur E. (C), Old Field Rd., Southbury, Conn.

CANADA

Weller, M. A. (D), 508 Walmer Rd., Saskatoon Sask, Canada.

CHICAGO

Goldstein, Joe (B), Inland Steel Co., East Chicago, Ind.
Lake, Albert H. (B), Electro-Motive Div., General Motors Corp., Engineering Dept. 80, La Grange, Ill.
Swider, Edward (B), Bates Expanded Steel Corp., E. Chicago, Ind.

CINCINNATI

Webb, Baxter (C), Webb Sales Co., 111 Pendery Ave., Wyoming, Ohio.

CLEVELAND

Adams, James L. (C), 1038 E. 148th St., Cleveland 10, Ohio.
Collens, Jonathan L. (C), Reliance Electric & Engrg. Co., 1088 Ivanhoe Rd., Cleveland, Ohio.
Estebo, Bert (C), 4405 Burger Ave., Cleveland, Ohio.
Fahey, Timothy Connolly (C), National Cylinder Gas Co., 1151 E. 222nd St., Euclid 17, Ohio.
Freundlich, Richard (C), Lincoln Electric Co., 12818 Coit Rd., Cleveland, Ohio.
Gallagher, E. W. (C), 4100 E. 100 St., Cleveland, Ohio.
George, Richard E. (C), National Cylinder Gas Co., 1151 E. 222nd St., Euclid 17, Ohio.
Greek, Clarence E. (C), 5819 Superior Ave., Cleveland 3, Ohio.
Grow, James (C), Glascote Prods., Inc., 20900 St. Clair Ave., Euclid 17, Ohio.
Hofmann, E. M. (B), Speedline, Inc., 2300 Payne Ave., Cleveland, Ohio.
Hunter, Clarence George (C), 3423 Fortune Ave., Parma, Ohio.
McCreery, R. D. (C), H. L. McCreery & Son, 2036 E. 22nd, Cleveland 15, Ohio.
Schaefer, D. J. (C), 14412 Woodworth Rd., E. Cleveland 12, Ohio.
Schummer, Matthias A. (C), 5307 Denison Ave., Cleveland 2, Ohio.
Wayne, Richard J. (B), 17008 Eldamene, Cleveland, Ohio.
Wheeler, Riley L. (C), R. F. D. 1, Wickliffe, Ohio.

COLUMBUS

Brockmeyer, Joseph E. (B), Surface Combustion Corp., P. O. Box 267, Columbus 16, Ohio.
Frim, John (B), 1924 Dyer Rd., Grove City, Ohio.
Snodgrass, John N. (B), Capital City Welding Co., 857 King Ave., Columbus, Ohio.
Warthen, Jesse C. (C), 224 Park St., Lancaster, Ohio.

DETROIT

Anthony, Andre A., (B), Super-Arc Welding Co., 6400 Brush St., Detroit 2, Mich.
Bierderman, Edward (B), 13961 Indiana, Detroit 4, Mich.
Lang, W. Claude (B), Rt. 1, Walled Lake, Mich.
Piggott, Charles W. (B), 9606 Ward Ave., Detroit 27, Mich.
Sheehan, Joseph E. (C) 2214 Chevrolet Ave., Flint, Mich.
Sinclair, Jack (B), Super-Arc Welding Co., 6400 Brush St., Detroit 2, Mich.
Smith, M. C. (B), Brooks & Perkins, 1957 W. Lafayette, Detroit 16, Mich.
Smith, Wm. E. (B), Midland Steel Prods., Detroit 11, Mich.
Thorden, Leonard (B), Dockson Corp., 3839 Wabash Ave., Detroit, Mich.
Turner, Myron W. (C), The Electric Storage Battery Co., 8051 West Chicago Blvd., Detroit 4, Mich.
Williams, Howard L. (B), 956 W. Lewiston Ave., Ferndale 20, Mich.
Williams, J. J. (B), Dockson Corp., 3839 Wabash Ave., Detroit 8, Mich.
Winney, Jack E. (B), 19717 Sumner Rd., Redford Township, Mich.

HARTFORD

Baraw, Stuart (B), 54 Perkins St., Manchester, Conn.
Douglas, Leroy (C), 190 Church Ave., Forestville, Conn.
Pulcini, Anthony (B), Kensington Welding Co., Box 25, Kensington, Conn.

INLAND EMPIRE

Stanke, Glenn K. (B), So. 708 Lake St., Colfax, Washington.

KANSAS CITY

Abbott, H. E. (B), Rte. 1, Box 312, Kansas City, Kans.
McCool, Kenneth L. (B), Standard Steel Wks., 16th Howell, No. Kansas City, Mo.
Morris, Curtis F. (B), 4109 Troost Ave., Kansas City, Mo.

LONG BEACH

Brothers, C. B. (C), C. B. Brothers Welding Service, 2320 Oregon Ave., Long Beach 6, Calif.
Preston, Jr., Clyde W. (C), 1117 Greenleaf Dr., Compton, Calif.
Yost, Harry W. (C), 3453 Gaviota, Long Beach 7, Calif.

MARYLAND

Fritz, Charles F. (C), 607 Washburn Ave., Baltimore 25, Md.

MICHIANA

Berkowski, Herman (B), P. O. Box 101, La Porte, Ind.

MILWAUKEE

Abendroth, George H. (C), Worden Allen Co., P. O. Box 2057, Milwaukee, Wis.
Bartos, Anton J. (C), 2841 No. 53rd St., Milwaukee 10, Wis.
Berry, E. J. (C), 2467 N. 71st St., Milwaukee, Wis.
Brethorst, Wilfred E. (C), 800 Pleasant St., Waukesha, Wis.
Bruschi, Daniel J. (B), 1236 Oak St., Beloit, Wis.
Burdick, Clement (C), 1235 No. 72nd St., Milwaukee, Wis.
Downing, Donald R. (C), Weldments Co., 1916 So. 3rd St., Milwaukee, Wis.
Englert, Oscar (C), 2156 No. 42nd St., Milwaukee, Wis.
Fairbanks, Ned (C), 6300 W. Silou Spring Dr., Milwaukee, Wis.
Foster, C. T. (C), 125 E. Greenfield Ave., Milwaukee 4, Wis.
Gade, Harold N. (C), 2664 So. 31st St., Milwaukee 7, Wis.
Greymont, Stanley (C), The Transport Co., Cold Spring Shops, N. 40th & W. McKinley, Milwaukee, Wis.
Groeki, Joseph (C), Superior Steel Prods., 1007 So. 8th St., Milwaukee, Wis.
Gruss, William (C), 5437 W. Cherry, Milwaukee, Wis.
Gustafson, Kurt O. (C), 3822 No. 24th. Place, Milwaukee 6, Wis.
Hahn, Elmer (C), 2419 N. 69th St., Wauwatosa 13, Wis.
Hoffman, Wm. E. (C), Trent Engineering, East Troy, Wis.
Holcomb, Albert A. (C), 2122 A. N. 16th St., Milwaukee 5, Wis.
Hoppe, Herbert R. (C), 3714 N. 24th Place, Milwaukee, Wis.
Jahncke, Kenneth (C), Chain Belt Co., 3132 A. N. 21st St., Milwaukee 6, Wis.
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Klug, Otto David (C), 1526 So. 14th St., Milwaukee 4, Wis.
Koss, John (C), 2134 N. 24th St., Milwaukee, Wis.
Kothrade, Elmer (C), 2475 N. 69th St., Wauwatosa, Wis.
Kranite, Arthur (C), 1422 N. 50th Pl., Milwaukee, Wis.
Krasonya, E. (C), 4211 North Water St., Milwaukee 2, Wis.
La Dew, Clifford J. (C), 2138 N. 26th St., Milwaukee 5, Wis.
Landis, Joseph W. (C), 4635 N. 37th St., Milwaukee, Wis.
Lohman, Raymond (C), Raylo Welding & Elec. Supply Co., 1210 N. Water St., Milwaukee 2, Wis.
Mader, C. J. (C), Tri Clover Machine Co., P. O. Box 97, Cudahy, Wis.
Malm, Harry W. (C), S & M Mfg. Co., 1820 So. K. K., Milwaukee, Wis.
Marquardt, James A. (C), 225-A N. 41st St. Milwaukee 8, Wis.
McNabb, Charles (C), 1620 Murray Ave., Waukesha, Wis.
Meddaugh, Curtis (C), 1832 So. 23rd St., Milwaukee, Wis.
Melicher, Ervin (C), F. W. Burns Machinery Co., 1730 W. North Ave., Milwaukee, Wis.
Metzger, William (C), Bradley Washfountain Co., 2203 W. Michigan Ave., Milwaukee, Wis.
Miracky, Frank (C), 3524 North 40th St., Milwaukee 10, Wis.
Navak, Frank A. (B), International Harvester Co., W. Bruce St., Milwaukee, Wis.
Newman, Wilbert W. (C), 2950 N. 1st St., Milwaukee, Wis.
Norship, Jesse (C), 3535 So. 58th St., Milwaukee, Wis.
Petry, Phillip C. (C), Harnischfeger Corp. 4400 W. National Ave., West Allis, Wis,
Pie, Arthur L. (C), R. R. 1 Box 482, Racine, Wis.
Rolland, Richard (C), 1302 So. 53rd, Milwaukee, Wis.
Schade, Karl (C), 510 E. Main St., Menomonce Falls, Wis.
Souhrada, Albert H. (B), 2803 W. Burnham St., Milwaukee 4, Wis.
Stucil, Frank (C), 973 So. 61st St., Milwaukee, Wis.
Svanoe, W. H. T. (B), Svanoe Co., 6318 W. State St., Milwaukee 13, Wis.
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Von Rohr, E. Jeane (C), 4125 N. Sherman Blvd., Milwaukee 9, Wis.
Waidhas, Gustav M. (C), 3035 West Wisconsin Ave., Apt. 405, Milwaukee 8, Wis.
Wendorf, Albert E. (C), Wisconsin Gasket & Mfg. Co., Granville, Wis.
Werra, Bruno (C), Tri Clover Machine Co., P. O. Box 97, Cudahy, Wis.
Wolfe, Guy L. (C), Fulton Co., 1912 S. 82nd St., Milwaukee, Wis.

NEW JERSEY

Cornell, Jr., F. G. (C), Jensen Machinery Co., Inc., Nelson St. at Locust Ave., Bloomfield, N. J.
Springer, J. L. (C), 55 Morgan Place, No. Arlington, N. J.
Starner, Philip W. (B), 444 Mountainview Terrace, Dunellen, N. J.

NEW YORK

Dodge, Cleon C. (C), The Taylor-Winfield Corp., Suite 1239 Chrysler Bldg., 135 E. 42nd St., New York 17, N. Y.
Franson, Eric C. (B), 8 Denton Place, Roosevelt, N. Y.

NORTHERN N. Y.

Becker, R. Condit (D), 1850—12th Ave., Watervliet, N. Y.
Linden, Carl A. (C), General Electric Co., Bldg. 41, Schenectady, N. Y.

NORTHWEST

Akins, C. M. (A), Marquette Mfg. Co. Inc., 307 East Hennepin Ave., Minneapolis 14, Minn.
Baker, Clifford J. (B), 2 East Allen Ave., Duluth, Minn.
Barnard, Richard L. (C), 3917 Thomas Ave So., Minneapolis 10, Minn.
Elem, Robert H. (B), 4916 Bryant Ave. No., Minneapolis 12, Minn.
Goetz, Edgar A. (B), St. Paul Fdry. & Mfg. Co., 500 Como Ave., St. Paul 3, Minn.
Green, Floyd L. (B), 642 Pleasant Ave., St. Paul, Minn.
Lynch, Glendon (C), St. Paul Hydraulic Hoist Co., 2207 University Ave. S.E., Minneapolis 14, Minn.
Sobanski, Edward J. (C), St. Paul Hydraulic Hoist Co., 2207 University Ave. S.E., Minneapolis 14, Minn.

NORTHWESTERN PA.

Ellsworth, Milton (B), R. D. 1, Harbor Creek, Pa.
Goss, R. N. (B), R. N. Goss Gas Prods., 17 W. Seventh St., Oil City, Pa.
Goss, Wildred Filson (C), R. N. Goss Gas Prods., 17 W. Seventh St., Oil City, Pa.
Johnston, Robert T. (C), National Cylinder Gas Co., 1151 E. 222nd St., Euclid, Ohio.
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PHILADELPHIA

Merchant, H. F. (C), The Progressive Welder Co., 808 West Ave., Jenkintown, Pa.
Wyche, Ernest H. (B), Lunkenweld, Inc., Lunkenweld Laboratory, Coatesville, Pa.

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Brace, Arthur A. (C), Arcway Equipment Co., 313 6th Ave., Pittsburgh, Pa.
Dykeman, Howard E. (B), Heyl & Patterson, Inc., 55 Water St., Pittsburgh 22, Pa.
Griffiths, Carl B. (B), Allis-Chalmers Mfg. Co., Columbus & Preble Aves., N. S., Pittsburgh 12, Pa.
Inskeep, Leo A. (B), 1249 Oak Grove Ave., Steubenville, Ohio.
O'Malley, Paul W. (C), Mellon Inst. of Industrial Res., Pittsburgh 13, Pa.
Zoog, H. J. (C), Main St., Hickory, Pa.

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Gewalt, George (C), 4253 22nd St. W., Seattle, Wash.

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Gentry, J. Claude (C), Owens-Illinois Glass Co., Alton, Ill.
Roberts, J. D. (C), Harnischfeger Corp., 4030 Chouteau Ave., St. Louis, Mo.
Salsich, P. W. (C), The Linde Air Prods. Co., 4228 Forest Park Blvd., St. Louis 8, Mo.

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Block, Edwin Joseph (C), 234 15th Ave., San Francisco, Calif.
Coleman, C. B. (B), 2132 High St., Oakland 1, Calif.
Passalacqua, Edward F. (C), 3879 22nd St., Apt. 4, San Francisco, Calif.

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Reagan, James O. (B), P. O. Box 2567, Houston, Tex.
Shidel, H. R. (B), Sec. 16—1121 Rothwell St., Houston 2, Tex.

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Goll, Jr., Charles (C), 328 W. Willow St., Syracuse, N. Y.
Roe, Robert, (C), 233 Carbon St., Syracuse 8, N. Y.
Smith, Claude F. (C), 282 Hood Ave., Syracuse 8, N. Y.

TOLEDO

Welch, Sr., Duraine E. (B), 191 Circular St., Tiffin 14, Ohio.

WESTERN MASS.

Roberts, Louis (B), Box 135, Wales, Mass.

WESTERN N. Y.

Schliecker, George H. (C), Industrial Equipment Co., 170 Franklin St., Buffalo 2, N. Y.
Wooldridge, Frank A. (C), U. C. and C. Research Labs., 4625 Royal Ave., Niagara Falls, N. Y.

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Whitt, Roy (C), 1724 Salina, Wichita, Kans.

WORCESTER

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Krapas, Vitte, J. (C), 44 Coral St., Worcester 4, Mass.
Le Blanc, Alfred (C), 412 Pleasant St., Worcester, Mass.
Trilligan, James L. (C), 392 Main St., Saundersville, Mass.
Waitkevich, Vittie (C), Malmo Rd., Worcester, Mass.
Wenc, William F. (C), 26 Sycamore St., Millbury, Mass.

NOT IN SECTIONS

Chapman, Raymond N. (B), 543 Lake Ave., Manchester, N. H.
Corstorphine, John (C), % The Burmah Oil Co., 'B C', Ltd., Chauk, Upper Burma, India.
Cullin, Jack (B), Ferrocarril Central Del Peru, Casilla 64, Callad, Peru, S. A.
Dewey, Alvin O. (B), 255 Tuttle Ave., Mobile 19, Ala.
Dodd, Thomas G. (B), 810 Merchants Bank Bldg., Mobile 13, Ala.
Frisbie, W. J. (B), 810 1st National Bank Annex, Mobile 13, Ala.
Geffroy, Robert R. (B), 3 One Du Pare, Levallois 'Seine,' France.
Hartley-Latshaw (B), Mobile Pulley Wks., Ann St., Mobile 20, Ala.
Hedlund, Sven J. (B), Vanadisvagen 20, Stockholm, Sweden.
Keel, Carl G. (C), Weiherweg 66, Bale, Switzerland.
Lee, Yung-Cheng (B), 537 Liaoyang Rd., Shanghai, China.
Lober, Charles G. (B), Dixie Steel Mfg. Co., Columbia Rd., P. O. Box 3155, Memphis 9, Tenn.
Luckie, M. Y. (B), 51 So. Bayou St., Mobile 21, Ala.
McKinney, Jr., Wallace R. (B), Lehay & Landry Plumbing Co., 154 So. Franklin St., Mobile 21, Ala.
Moller, Sverre (B), A-S F. M. V., Fredrikstad, Norway.
Sabelstrom, Sture (B), Stockholmsvagen 84, Enskede, Sweden.
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Titus, James Stanford (C), Great Rd., Saylesville, R. I.
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Employment Service Bulletin

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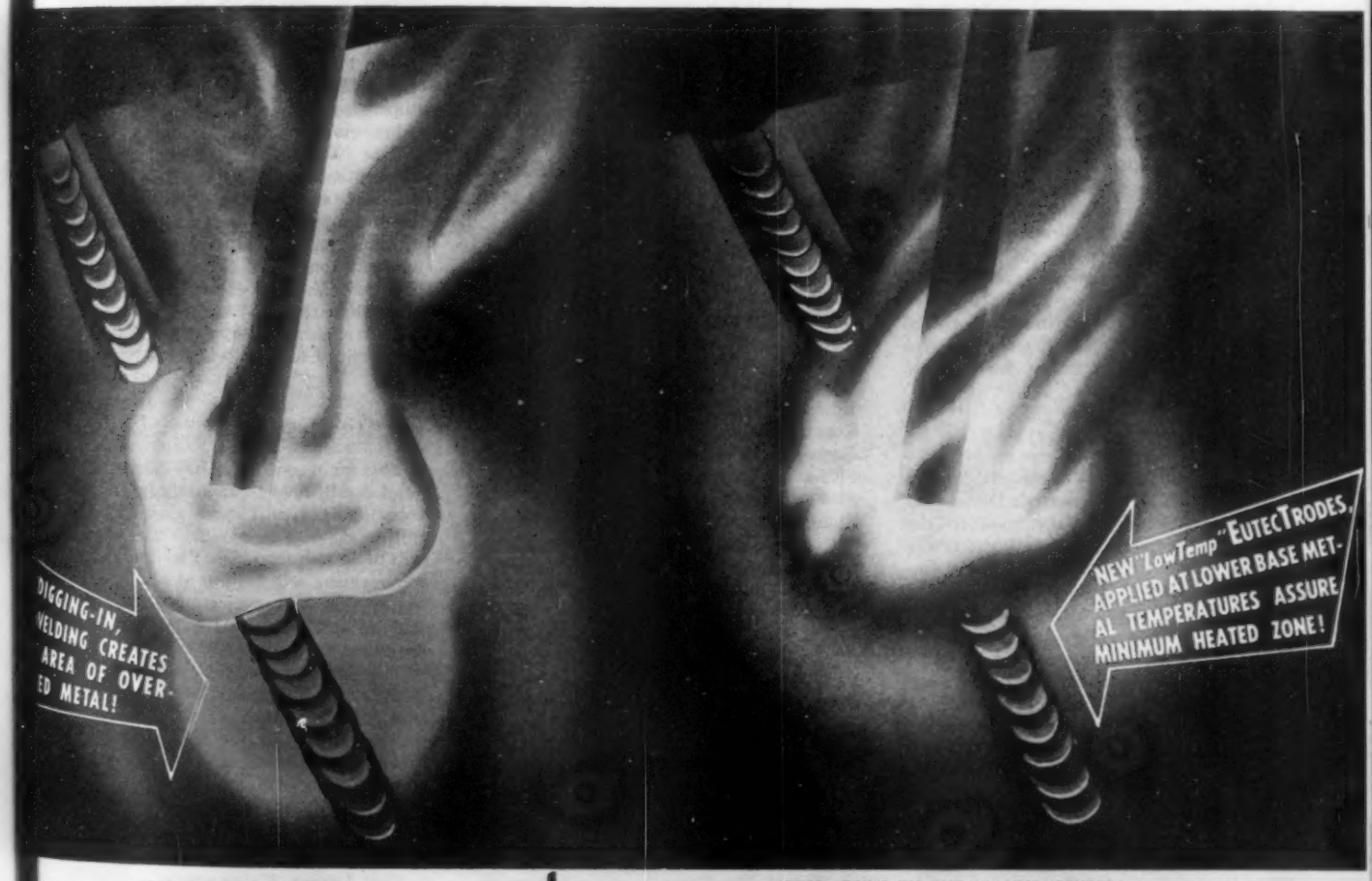
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SECTION ACTIVITIES

BOSTON

On January 6th, the Boston Section of the American Industrial Radium and X-Ray Society held a joint meeting with the Boston Section of the A.W.S. The speaker of the evening was Mr. E. F. Tibbetts, Engineer with the Bethlehem Steel Company, Shipbuilding Division, Quincy, Mass. Speaking on the subject of "Quality Control in Production Arc Welding," Mr. Tibbetts described in detail the application of X-Ray, Magnaflux, probe, and other nondestructive tests used in quality control of arc-welding in the fabrication of large structures and gave data showing the results of these tests performed on many thousands of feet of welding. Mr. Tibbetts is a past president of the Boston Section, American Industrial Radium and X-Ray Society, and is in charge of quality control testing at the Quincy Shipyard.

The after-dinner speaker was Mr. B. B. Beebee who gave an illustrated talk, using movies, on the "Private Life of the Honey Bee."

CINCINNATI

Mr. L. G. Pickhaver, Welding Engineer, General Electric Co., Chicago, presented a very interesting talk on "Three Gaseous Shielded Arc Welding Processes," at the November 26th meeting held in the Engineering Society Headquarters. After a very interesting meeting, which included technicolor motion pictures and slides, all members and their guests enjoyed a Dutch lunch held at the Engineering Society rathskeller.

CLEVELAND

Robert D. Williams, Assistant Supervisor of the Welding Research Division of Battelle Memorial Institute, spoke to the Cleveland Section at its monthly meeting held on January 8th at the Cleveland Engineering Society. His subject was "Flash Welding of Hard-Drawn Carbon Steel Wire."

Mr. Williams is a graduate of Harvard and M.I.T. and was instructor in Heat Treatment and Welding Engineering at the University of Illinois before he came to Battelle in 1942. Author of many technical papers on welding, Mr. Williams is a member of the A.W.S., A.S.M.E., A.I.-M.M.E., A.S.M. and Sigma Xi.

Coffee talk was given by Gordon Cobbledick, sports editor of the Cleveland *Plain Dealer*, who related numerous stories and anecdotes concerning big league ball players who have played in the past 20 years. Cobbledick, who is a graduate of Case and was star football player there, served in the Marines in World War I and was a war correspondent in World War II, writing a daily column for the Cleveland *Plain Dealer*.

DAYTON

An informal Christmas Dance was held by the Dayton, Ohio, Section at The Dayton Canoe Club on Friday, December 20th, for members only. Plans for a big evening in celebration of the first anniversary of the Section were made by the program committee. The dance will be remembered by the members for a long time to come. A buffet lunch was served during the evening and a good time was had by all.

Mr. E. B. Lutes, Welding Engineer for Arcrods Corp. of Sparrows Point, Md., was the guest speaker at the January 22nd meeting held at the Engineers' Club. His topic was "A New Field of Electrode Developments."

During the time Mr. Lutes has been with the Arcrods Corp., his duties have consisted of inspection and quality control, research and development, and at the present time he heads the Department of Welding Engineering. He is a member of the AMERICAN WELDING SOCIETY and the American Society of Metals.

DETROIT AND SAGINAW VALLEY

The fifth meeting of the season was held on January 10th by the Detroit Section and on January 9th by the Saginaw Valley Division. The program was as follows: "Welding of Aluminum Sheet in Automotive Construction," L. A. Danse, Chairman of Symposium and Chairman, Metallurgical Committee, General Motors Corp. The Panel consisting of Neil Wheeler, General Motors Corp., Truck & Coach Division; Charles Carter, Murray Corporation of America; Jack Ogden, Fisher Body Division; G. O. Hoglund, Aluminum Company of America; W. Claude Lang, Chrysler Corp., participated in the Symposium on "What happened to the small car that advertised an aluminum body?" "Are the Aluminum companies ready with suitable alloys?" and discussed other pertinent questions.

HARTFORD

A dinner meeting was held on December 19th at the City Club. D. H. Corey, Welding Engineer, The Detroit Edison Co., spoke on "Welding of Pipe for Severe Service Conditions." The Section was very fortunate in being able to secure a speaker of Mr. Corey's caliber for an address on the important subject of pipe welding, because his education and experience place him among the country's leading authorities on this subject. Mr. Corey has been connected with the Detroit Edison Co. since his graduation from the University of Wisconsin with the degree of B.S. in electrical engineering.

The January 16th meeting, held at the University Club of Hartford was addressed by J. K. Light, District Manager and Field Engineer, Arcos Corp., Hartford Conn. Mr. Light's subject was "Problems Encountered in Stainless Steel Welding." Mr. Light has been actively connected with the fabrication of metals since 1932 when he joined the John Wood Manufacturing Co. as Design Engineer in building of storage systems, pressure vessels, etc. In 1944 Mr. Light joined the Arcos Corp. where he is at present Assistant to the Sales Manager; Field Engineer, Research and Engineering Dept.; and District Manager of the New England District.

Mr. Light's subject was both timely and interesting in that stainless steel is playing an ever-increasing part in the modern world of metals and its weldability should be understood by everyone connected with the fabrication of repair of this wonder metal.

The February 20th meeting will be addressed by H. S. Swan, General Welding Supervisor, American Locomotive Co., Schenectady, N. Y. Mr. Swan's subject will be "Welding the Modern Steam and Diesel Locomotive."

The March 20th meeting will be addressed by Dr. Wendell F. Hess (past-president of the AMERICAN WELDING SOCIETY), Rensselaer Polytechnic Institute Troy, N. Y. Dr. Hess's subject will be "New Frontiers in Welding."

Meetings hereafter will be held at The University Club, 30 Lewis St., Hartford.

KANSAS CITY

The night on which the Kansas City Section will hold its monthly meeting has been changed to Thursday of the second full week of the month. The meeting will be in two sections. The informal dinner meeting will be 6 P.M. at Fred Harvey's. The business meeting and program will be at 8 P.M. in the Power & Light Building.

The January meeting was held on the 16th. R. S. Babcock, Development Division, The Linde Air Products Co., spoke on "Stack Cutting and Plate Edge Preparation." A lively discussion followed.

LEHIGH VALLEY

The Lehigh Valley Section held its monthly meeting on December 2nd at the Hotel Bethlehem, Bethlehem, Pa.

The members and guests attending the dinner were given an archery exhibition by Paul Cowin and Bob Smith, two of the Lehigh Valley's top archers.

Dr. Gilbert E. Doan, the chairman, presided at the dinner meeting. The dinner

was followed by a technical meeting. C. L. Kreidler introduced the speaker of the evening, R. P. Palmer of the Wheeling Steel Corp. Mr. Palmer's subject was "Maintenance Welding." He discussed general steel mill maintenance welding, covering such subjects as crane rail welding, repairs to large babbitt bearings, soaking pit covers, etc. The speaker's remarks were followed by an interesting floor discussion.

The January meeting was held on the 6th in the University Room of the Hotel Bethlehem.

The after-dinner speaker was W. A. Bender, a member of the Commission of Health & Safety for the Bethlehem Boy Scout Council. Mr. Bender's subject was "Safety of Fire Arms."

Prof. C. D. Jensen, of Lehigh University, introduced the following Panel members, who are members of the Philadelphia Section: Dave Thomas, Jr., Arcos Corp., who spoke on "Electrode Specifications"; John D. Bert, Philadelphia Navy Yard, "Inspection of Fusion Welding"; John L. Lang, Lukenweld, Inc., "Qualification of Operators."

The meeting was one of the most interesting of the current series, the discussion was lively and the members of the Panel very capably answered all queries.

LOS ANGELES

The December meeting was held as a get-together to renew acquaintances and to see old friends by way of an annual Christmas Party. The party was held on December 20th at the Rio Hondo Country Club with an attendance of about 250. From all observations, there was never a dull moment. The Christmas Spirit was very much in evidence with cheer and presents. The local sales companies in the industry donated the presents, which were given by number to the lucky ones who had a corresponding number drawn. Al Fenlason, of Consolidated Steel, did the honors in presenting the gifts.

At the January meeting, the very able Alex Maradudin, Chief Metallurgist for the Standard Oil Co., presented the use of polarized light in respect to tension and destruction characteristics of plastic test specimens.

The February 21st meeting will be a plant visitation and dinner for members only by the Consolidated Seeel Corporation, Maywood.

The March 20th meeting will be addressed by Mr. LaMotte Grover of the Air Reduction Sales Company, New York City, who has consented to talk on general welding applications.

LOUISVILLE

The December meeting of the Louisville Section was held on the 17th in the Chemical Engineering Building, University of Louisville. G. W. Plinke, research director at the Henry Vogt Machine Co., spoke on the subject "Meeting the Requirements of Various Codes and Specifications and Qualification of Process and Operator for High-Pressure, High-temperature Welded Parts." Mr. Plinke discussed the essential requisites for high-pressure welding to meet the rigid demands of various codes and specifications. He outlined the details of qualification of various processes and requirements for operators. The talk was illustrated with slides and specimens.

MARYLAND

The first meeting of the 1947 season was held on January 17th at the Baltimore Engineers' Club. Arthur H. Senner, U. S. Naval Engineering Experiment Station, Annapolis, Md., presented an interesting Coffee Talk on Gas Turbines. This talk featured a sound movie, "Tornado in a Box," by courtesy of the Allis-Chalmers Co.

The technical session at 8 P.M. consisted of a paper entitled "Fundamentals of Re-Design for Fabrication by Welding" presented by Gerald von Stroh of the Lukens Steel Co. This paper was very ably handled by the speaker and was illustrated with slides. An open discussion and refreshments followed the main talk of the evening.

MICHIANA

December meeting was held on the 20th at the Bendix Legion Post. Mr. Leon C. Bibber, Welding Engineer with the Carnegie-Illinois Steel Corp., Pittsburgh, presented a most interesting talk on Design in Welding.

MILWAUKEE

The regular December meeting was postponed to January 3rd because of conflict with the holidays.

The session was devoted to spot welding and, to make the evening complete, the Coffee Talk was devoted to "Power Supply for Spot Welders." Almer Skretting, of the Wisconsin Electric Power Co., spoke briefly about the problems which the utility companies face in supplying power for resistance welders in general and especially for the larger sizes. It was pointed out that if resistance welders can be kept off the circuit used primarily for city lighting there are fewer problems.

The main speaker of the evening was J. H. Cooper, Chief Sales Engineer of the Taylor-Winfield Corp. Mr. Cooper first showed a film entitled "This Is Resistance Welding," which showed many applications of spot, seam and projection welding. This technicolor film is very well done.

Mr. Cooper then discussed the four outstanding developments in spot welding which occurred during the war period, the most significant being the spot welding of armor plate. A series of slides showed many applications of spot, seam and projection welding processes ranging from tiny wires of electronic tubes to large industrial equipment.

The educational program which was begun last year was continued. A series of five evening lectures on "Welding Metallurgy" were held at Marquette University, starting promptly at 7:30 P.M. This course was designed to present some of the fundamental metallurgical differences of various metals and the metallurgical aspects of welding those metals normally encountered in industry. The first lecture was held January 6th and the fifth, and last, on February 3rd.

NEW JERSEY

The regular monthly meeting of the New Jersey Section was held on December 17th at the Hotel Essex House. J. B. Arthur, Westinghouse Electric Corp., Buffalo, N. Y., spoke on "Design for Automatic Welding." Mr. Arthur's paper was both instructive and interesting, characterized by excellent presentation.

A Powder-Flux-Arc Oxygen Cutting Forum was held on Monday, January 6th, in the Public Service Auditorium, Newark. Robert Pursell lead the Forum. A lively discussion, due to the wide interest in these processes, took place. Slides and a film were shown through the courtesy of the Air Reduction Sales Co., The Linde Air Products Co. and Arcos Corp. Experts from producers and users of the process were on hand to answer questions.

NEW YORK

The December meeting of the New York Section was held on the 11th at the Engineering Societies Building. The speaker was T. R. Lichtenwalter, Metallurgist, of Republic Steel Corp., Cleveland, Ohio. His subject was "The Welding and Finishing of Enduro Stainless and Heat Resisting Steels." Mr. Lichtenwalter's discussion aroused a great deal of interest among those attending and members of the audience asked questions for more than one hour.

The January meeting was held on the 8th in the Engineering Societies Building. Paul Klain, Research Metallurgist, of the Dow Chemical Co., Midland, Michigan, spoke on "Some Considerations in the Welding of Magnesium Alloys." Mr. Klain's talk touched briefly on the history of the production of magnesium, the characteristics of the metal, and its most commonly used alloys. He spoke at some length on the welding processes with particular emphasis on the inert-gas-shielded arc welding process.

The meeting was preceded by a film "Working of Magnesium."

NORTHERN NEW YORK

F. E. McAtee, Welding Engineer of the Chicago Bridge & Iron Co., will be the speaker at the February 27th meeting. His subject will be "The Safety of Large Field-Welded Pressure Vessels." The talk will discuss spheres, spheroids and blimps, and their behavior under test and in service. It will include a description of inspection methods and quality control during construction, and a discussion of some partial and complete failures which have occurred and the lessons learned therefrom.

NORTHWEST

The January meeting was held on the 16th in the Lodge Room of the Covered Wagon, Minneapolis. W. G. Boese, Weld-

ing Engineer, Pullman-Standard Car Mfg. Co., Michigan City, Indiana, spoke on the subject "Welding in Transportation." Mr. Boese is an outstanding authority on this subject. He has been in charge of welding operations of the freight car division of his company since 1926.

PEORIA

The December meeting was held on the 18th at the Caterpillar Tractor Showroom Theatre. Members and guests saw a film entitled "Building a Better World," after which they were conducted on a tour through the Caterpillar Tractor Co. Sheet Metal Structural Steel Fabrication Shop and Welding Department. The meeting was concluded with a discussion period.

PHILADELPHIA

The regular monthly meeting for December was held on the 16th at the Engineers' Club. H. W. Lawson, of the Ingalls Iron Works Co., spoke on the subject "Modern Structural Welding Design and Practice."

A joint meeting with the Society of Naval Architects was held on January 20th in the Philadelphia Electric Co. Auditorium. Franklin H. Pennell, of the DeLaval Steam Turbine Co., spoke on the subject "Welding of Ship Propulsion Machinery." Discussion on this subject was given by Norman Mochel, of the Westinghouse Electric Corp., and Arthur Holzbaur, of the Sun Shipbuilding and Drydock Co

The dates of the last three Panel Discussion Meetings are March 7, April 4 and May 2.

ROCHESTER

The Rochester Section held its fourth meeting of the current season on January 9th, in the Engineering Building, University of Rochester. A. N. Kugler, of the Air Reduction Sales Co., New York, spoke on the subject "Jigs and Fixtures for Welding." Mr. Kugler presented his material in a most interesting manner with numerous slides to illustrate the construction of jigs and fixtures and their utilization. Many ingenious fixtures used by the shipbuilding, railroad and aircraft industries, welded up from pipe and miscellaneous structural steel members, aided war production immeasurably.

ST. LOUIS

On December 13th the St. Louis Section conducted an informal smoker at The Candle-Light House in St. Louis. The meeting was attended by seventy-five members.

SOUTH TEXAS

Walter J. Brooking, Dean, LeTourneau Technical Institute, spoke on "Economics of Arc Welding" at the December 12th meeting held in the Taylor School Auditorium. Mr. Brooking discussed means of cost control through proper fit-up for welding, design, welding technique, etc., and presented figures to show the rapid increase in cost that results from "over welding."

SYRACUSE

The December 11th meeting held at the Hotel Syracuse was addressed by G. N. Sieger, President of S.M.S. Corp., who spoke on "Resistance Welding." A motion picture film, "This Is Resistance Welding," was also shown. Both the film and paper were very well received by those present. This was the largest attended meeting of the year.

The January meeting was held on the 8th at the Hotel Syracuse. Charles H. Jennings, Welding Engineer, of Westinghouse Electric Corp., spoke on "Distortion Problems." A film, "Skiing on Top of the World," was shown through the courtesy of General Motors. Both were very well received.

WASHINGTON

On December 11th, the Washington Section, acting as host at a joint meeting with the Washington Chapter of the American Society for Metals, presented Vice Admiral Harold G. Bowen, who spoke on "Metallurgical Research." Admiral Bowen outlined the policies of the Navy and its plans for the furthering of fundamental research not only within the Government, but in the universities and in industry. The large audience questioned the Admiral closely, and seemed quite impressed with the ambitious programs planned for the future.

WESTERN MICHIGAN

F. J. Lammers, Secretary, Wallace Supplies Mfg. Co., Chicago, presented a talk on "Welding Problems in Jet Propulsion—Stainless Steel," at the December 9th meeting held in the Association of Commerce Cafeteria. Dinner preceded the meeting.

WESTERN NEW YORK

Harry W. Pierce, of New York Shipbuilding Corp., spoke on "Control of Distortion in Weldments and Welded Structures," at the September 26th meeting held in the Hotel Touraine.

Carl M. Underwood, Manager, Welding Dept., Northern Ordnance, Inc., spoke on "Modern Arc Welding Practices" at the October 24th meeting held in the Hotel Touraine. After-dinner speaker was Bud Trefts, President of Farrar and Trefts, Inc., who spoke on "What We Do in Our Shop."

D. H. Corey, Welding Engineer, The Detroit Edison Co., Spoke on "Welding Pipe for Severe Service Conditions" at the December 5th meeting held in the Hotel Touraine.

Dr. G. E. Claussen of the Reid-Avery Co., Inc., of Baltimore, Md., was the guest speaker at the January 23rd meeting. Dr. Claussen's subject was "Recent Trends in Arc Welding Electrodes," which was supplemented by a film showing welding in slow motion.

The February 27th meeting will be addressed by A. M. Setapan of Handy and Harman, who will speak on "Low Temperature Brazing."

WORCESTER

A dinner meeting of the Worcester Section was held on December 10th at the Aurora Hotel. Guests of the evening were Aldermen James D. O'Brien, Philip B. Mulfey and C. Edwin Lofgren; Councilmen Roy E. Johnson, Eldridge E. Campbell, Clarence T. Rolander and John J. Kelley; Building Commissioners Willard Hedlund and Edward T. McCann of the Bureau of Public Buildings.

LaMotte Grover, Welding Engineer of the Air Reduction Sales Co., New York, was the guest speaker. His topic was "Structural Welding" and was illustrated by slides. He compared welded design with riveted structures, maintaining that welding is cheaper and stronger and, by raising the fiber stress, will save the builder and taxpayer considerable money. He also discussed building codes with regard to the proposed revision of Worcester's codes, to permit welding, which is in the process of being revised at the present time. His lecture was followed by a question period.

The January dinner meeting was held on the 7th at Howard Johnson's, Shrewsbury. R. H. Davies, Consulting Engineer, The Lincoln Electric Co., Cleveland, Ohio, presented an illustrated talk on "Cast Iron vs. Welded Fabrication." His talk was illustrated by two new sound and technicolor movies recently released by The Lincoln Electric Co.; the first dealing with the speaker's topic, and the second on "Structural Welding." Mr. Davies explained means of eliminating vibration and reducing cost in machine base welding.

YORK-CENTRAL PENNSYLVANIA

The December 4th meeting was postponed to Wednesday, December 11th. The subject, "Designing for Welding," was discussed by Marvin Silberger, American Chain Co., Frank Allen, York Corp., and Gus Ostrom, Alloy Rods Co., all members of the Section's Technical Advisory Committee. Material exhibit was by Wm. Hess of the Safe Harbor Wr. P. Co. A movie, "Designing Machinery for Arc Welding," was shown through the courtesy of The Lincoln Electric Co.

The January 8th meeting, held in the Engineering Building, York, Pa., had for its subject "Cutting and Fabricating for Welding"; speaker, A. B. Gordon, Supervisor, Process Service, The Linde Air Products Co. Mr. Gordon supplemented his talk with a series of slides showing actual operations being performed pertaining to the subject he discussed. A movie was shown through the courtesy of the Lukens Steel Company.

CANADIAN

The third meeting of the 1946–47 season of the Montreal Chapter, Canadian Welding Society, was held on Monday,

...FOR EASIER WELDING OF *DIFFICULT* JOBS

WELDING FLUX IS NOT REQUIRED!

—Even for such materials as aluminum and magnesium. Therefore, cleaning is simplified, and complete freedom of joint design is possible.

DISTORTION IS REDUCED! AND EFFECTS ON STRUCTURE AND PHYSICAL PROPERTIES ARE MINIMIZED!

—Because the welding heat is confined to the immediate weld area, subsequently cooled rapidly by the gas acting as a quenching medium, there is limited transfer of heat into the base material.

WELDS ARE FREE FROM OXIDATION!

—Are smooth and uniform and, in general, present an excellent appearance.

If your welding involves any of the above metals, you'll want a copy of bulletin GEA-4704 . . . tells the how and what of Inert-Arc welding.

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GENERAL ELECTRIC

December 16th in The Engineering Building, McGill University. The meeting was in the form of a "Stump the Experts" session with five experts in the art of welding as follows: Rod Ferguson, Dominion Bridge Co., Ltd.; Russ Dunn, Canadian Liquid Air Co.; Oscar Kobel, G. D. Peters & Co. of Canada, Ltd.; Gordon Mills, The Lincoln Electric Co.; and G. E. Raymond, Crane Ltd.

The fourth meeting of the season was held on January 20th. "The Welding of Light Gage Metals" was discussed by Harry Thomasson, Metallurgical Engineer, Canadian Westinghouse Co., Hamilton.

The fourth meeting of the season of the Toronto Chapter was held on January 6th at Malloneys Art Galleries. Harry Thomasson, Metallurgical Engineer, Canadian Westinghouse Co., discussed the subject, "The Welding of Light Gage Metals."

The fourth meeting of the Hamilton Chapter was held on January 7th at McMaster University. "Maintenance Welding" was discussed by A. J. F. MacQueen, Superintendent, Mechanical and Electric Department, Atlas Steels Limited, Welland.

DR. VANNEVAR BUSH TO RECEIVE HOOVER MEDAL, AWARD OF FOUR NATIONAL ENGINEERING BODIES

Dr. Vannevar Bush, President of Carnegie Institution of Washington, and wartime Director of the Office of Scientific Research and Development, has been named 1946 winner of the Hoover Medal, jointly awarded by four national engineering societies. The medal is of gold and bears the inscription: "Awarded by Engineers to a Fellow-Engineer for Distinguished Public Service."

It will be formally conferred on Dr. Bush on Thursday, January 30, at 1:45 P.M. in the auditorium of the Engineering Societies, 29 West 39th St., New York, at the winter meeting of the American Institute of Electrical Engineers. This society confers the award jointly with the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, and The American Society of Mechanical Engineers. These four national organizations, with a total membership of more than 82,000, are known as the engineering "founder" societies.

The citation for Dr. Bush reads as follows:

> "Engineer, educator, and administrator, who, in critical time of need, was in a most special sense an organizer, guiding spirit, and driving force of the nation's achievements in physical and medical science; to whom, for outstanding public service, is awarded the Hoover Medal for 1946."

Herbert Hoover First Winner

The award to Dr. Bush will be the ninth. The first medal was given in 1930 to Herbert Hoover, for whom it was named, in recognition of his humanitarian principles and public service.

The Hoover Medal was formally instituted in that year, at the fiftieth anniversary of The American Society of Mechanical Engineers. The trust fund creating the award was the gift of a Past-President of that society, the late Conrad N. Lauer. The fund is administered by the Hoover Medal Board of Award, consisting of three representatives from each of the four societies. It is in the permanent custody of the A.S.M.E. and is maintained in perpetuity.

Dr. Bush, named in 1941 as wartime chief of the Office of Scientific Research and Development, was chosen for the task of correlating research in the physical and medical sciences to advance the cause of the United States and its allies. It has been said that he "picked the best brains in the land;" 300 top industrial and academic laboratories, with some 6000 scientists and their aids, were at work under his general direction to implement victory for the allies.

Not only new weapons and instruments including the atomic bomb, but methods for saving lives were the concern of this coordinated effort; penicillin and other life-saving drugs, blood substitutes, treatments for malaria; radar and mechanical ears and eyes and thousands of other developments emerged through the efforts of the OPRD.

In the award of the Hoover Medal, Dr. Bush adds one more to a list of significant awards including the Holley Medal of The American Society of Mechanical Engineers; the Edison Medal of the American Institute of Electrical Engineers and the gold medal of the National Institute of Social Sciences. He is a graduate in electrical engineering from Tufts College and holds honorary degress from Tufts, M.I.T., Harvard, Brown, Middlebury College, Johns Hopkins, University of Pennsylvania, Yale, Polytechnic Institute of Brooklyn, Rutgers, Williams, and Stevens Institute of Technology.

He was on the Tufts faculty and on the faculty and later dean of engineering of M.I.T. He is a member of the National Advisory Committee for Aeronautics. He was former chairman of the National Defense Research Committee and formerly on the Business Advisory Council of the Department of Commerce.

He is the author of many technical works, including contributions to electrical engineering publications and others and has been widely quoted on the control of nuclear energy and its peacetime applications.

He is also the inventor of a differential analyzer, a machine for solving differential equations.

ADAMS LECTURE SERIES

In honor of its first President and Founder the AMERICAN WELDING SOCIETY created an honorary scientific lecture series known as the Adams Lecture. Each year the Lecture is awarded to some outstanding meritorious scientist or engineer. The reports have been issued in atrractive pamphlet form and are available at 50¢ each. They are as follows: 1944—Solid Phase Welding, by A. B. Kinzel; 1945—Selection of Steel for Welding, by S. L. Hoyt; 1946—New Frontiers in Welding, by Wendell F. Hess.

SILVER TIE-IN

Silver Tie-In is the name of a very handsomely illustrated book published by H. C. Price Co., Bartlesville, Oklahoma, depicting the development and growth of a progressive company. It is the romance of the development of arc-welded pipe lines

We quote below the introductory page.

"After Twenty-five Years

"The First Welding Machine we bought wouldn't make 'juice'—we had hooked it up backwards. Our first welded pipeline 'leaked in every joint'—we hadn't had enough experience.

"Looking back at it now, after 25 years, we can see the humor in these early struggles. With Canol, Big Inch, Little Big Inch and over 15,000 miles of other major pipeline jobs behind us, we can view our past trials philosophically and with a degree of pride. They were the testing rounds that made our later successes possible.

"These first failures were discouraging, but we were still convinced that there was a bright future in electric welding, especially as applied to oil and gas pipelines. Because you believed in us we were able to carry out our ideas and thus pioneer many improvements in the technique of pipeline construction—improvements which have cut the cost of welding pipelines over 40% since 1928.

"November 1, 1946, marks the 25th Anniversary of our company. As you read the Silver Tie-In we hope you will re-live with us some of the experiences of our first quarter-century in business."

Technical Activities Committee

Taken from Annual Report

By H. W. Pierce, *Chairman*

INTRODUCTION

During the past year the activities of the Society's technical committees have reflected the nation's transition from a wartime to a peacetime condition. This transition has necessitated a review of the activities of every technical committee, and frequently a reorientation of the work in progress. In the case of committees whose projects were interrupted at the start of the war, it has been necessary to reconsider the desirability of continuing and completing these projects, in the light of the changes that have come about since 1941. These studies have resulted in the reorganization or disbandment of several committees, as reported in detail below.

The Technical Activities Committee has strived to maintain and promote the Society's cooperation with government agencies, which was advanced to a considerable extent during the war period. This effort is based on a conviction that close cooperation between industry and the government will be to the advantage of both, and will be of inestimable value to the country in times of national emergency. A considerable degree of success has been realized in promoting this policy, as discussed in more detail hereinafter.

ADMINISTRATION OF TECHNICAL ACTIVITIES

The volume of work being performed by the Society's technical committees is now greater than at any previous time in the Society's history. To facilitate and expedite this work, the technical staff at Society Headquarters has been augmented by two additions, including the return of the Technical Secretary from service in the United States Army.

During the past year the Technical Activities committee has given further study to methods of publicizing the Society's codes, standards, recommended practices and committee reports. Releases to the technical press have been effective in providing widespread publicity of newly published standards, and have resulted in greater sales and increased interest in the Society's publications. Similar releases directed to the Society's Local Sections have not proved equally satisfactory. Experience has shown that a direct personal approach is more effective in acquainting the membership of the Local Sections with the standardization activities of the Society. Accordingly, a program has been initiated whereby members of the Headquarters staff will visit the Local Sections and deliver talks on the codes, standards and technical committee activities of the Society. Sections already visited or scheduled for visits during 1946 include Chattanooga, Cincinnati, Louisville, New Orleans and South Texas.

The Technical Activities Committee has also formulated another policy, with the approval of the Board of Directors. designed to promote more active participation on the part of the Local Sections in the technical committee activities of the Society. In accordance with this policy the Local Sections have been encouraged to designate a "technical activities representative" from each Section, whose functions would be: (1) to publicize in the Section information received from Society Headquarters relative to the codes, standards and technical committee activities of the Society; (2) to inform Society Headquarters of any items of interest to the technical committees that might develop in the Section; (3) to inform Society Headquarters of competent personnel in the Section who are available for service on technical committees. This policy was communicated to the Sections only recently, so that no results can be reported at the present time.

APPOINTMENT OF NEW COMMITTEES

During the past year there were no new A.W.S. Technical Committees appointed. However, the Society has assumed the sponsorship of an A.S.A. Sectional Committee on Safety in Welding and Cutting Operations. This Committee was organized under the Sectional Committee procedure of the American Standards Association, and will be engaged in preparing an American Standard on "Safety in Electric and Gas Welding and Cutting Operations." The American Welding Society, as sponsor of this Committee, has designated the Assistant Technical Secretary to serve as Secretary of this Committee and will take an active part in furthering the project.

REORGANIZATION OF EXISTING COMMITTEES

A.W.S. Aircraft Welding Committee

The work of this Committee has been conducted by an Eastern Division and a Western Division, operating under separate chairmen. Because of changes in circumstances brought about by the conclusion of the war production period, it was necessary for the Technical Activities Committee to reconsider the functioning and organization of this Committee. After completing their study, the Technical Activities Committee agreed to reorganize the Committee in such a way that there will be just one National Committee without separate Eastern and Western Divisions. The former Chairman of the Western Division was appointed temporary Chairman of the new Committee, and he was requested to undertake a detailed reorganization of the Committee, including reviewing the scope and personnel of the Committee and electing permanent officers. It is expected that this reorganization will be completed within a short time, after which the projects selected by the Committee will be initiated.

Committee on Pressure Piping

The principal accomplishment of this Committee has been the preparation of the welding provisions of the A.S.A. Code for Pressure Piping. This work was completed in 1942 and the Committee has been largely inactive during the war. On Sept. 18, 1946, a meeting was held to consider the future activities of this Committee. It was decided: (1) that there is need for an active A.W.S. technical committee to cover the field of welding of piping and tubing; (2) that the Committee's interests and activities should extend greatly beyond the welding provisions of the A.S.A. Code for Pressure Piping; (3) that the personnel of the present committee should be reconstituted with due regard to certain specific proposals for expansion of the functions of the Committee. These conclusions were referred to the Technical Activities Committee with a recommendation that appropriate steps be taken to reorganize the Committee on Pressure Piping along the lines indicated. These recommendations are presently being studied, and it is anticipated that a newly constituted A.W.S. Committee on Pressure Piping will be appointed in the near future.

Committee on Nondestructive Tests for Welds

This Committee has been largely inactive during the war and recently made plans to reinitiate their work. The question was raised, however, as to the relationship of this Committee to the Society's Committee on Recommended Practices for Inspection of Welding. This question was discussed at a meeting of representatives from the two committees concerned, at which it was decided that the two committees should be combined into a single committee with the title "Committee on Methods of Inspection." This recommendation, together with a proposed scope for the new Committee, was referred to the Technical Activities Committee for consideration. The subject is presently being studied and it is anticipated that the committee as proposed will be organized in the immediate future.

Committee on Recommended Practices for Inspection of Welding

(See above discussion on Committee on Nondestructive Tests for Welds.)

Committee on Standard Tests for Welds

In view of the discussion of the functions of the Committee on Nondestructive Tests for Welds and Committee on Recommended Practices for Inspection of Welding (see above), consideration was given to the redefinition of the scope of this Committee.

Inasmuch as problems related to nondestructive tests will come within the province of the new Committee on Methods of Inspection, it was decided that such nondestructive tests as radiography and magnetic-particle testing should not come within the scope of the Committee on Standard Tests for Welds. Accordingly the latter committee recommended to the Technical Activities Committee that its title be changed to "Committee on Standard Mechanical Tests for Welds," and that its scope should be stated as follows: "To develop standard methods of mechanical testing of welds for adoption by code- and specification-writing bodies and for general use; to aid in coordinating standard test methods as proposed by other bodies." This proposed change in title and scope is now being studied by the Technical Activities Committee.

Committee on Large Welded Pipe for Hydraulic Purposes

Prior to the war this Committee was engaged in the preparation of a code for welding of steel pipe of large sizes and intended for hydraulic purposes. This code was nearly completed, having reached the stage of a second draft, at the time the United States entered the war. It was then decided to hold the work in abeyance until the end of the war, for the reason that the committee members found it necessary to redirect their energies to matters of more direct concern to the war effort.

During the past year consideration was given to the desirability of completing the work on this code and having it published. It was discovered, however, that conditions in the field of penstock construction had changed considerably during the war, particularly since most of the penstock construction that has taken place in recent years has been under the jurisdiction of the Federal Government. The Technical Activities Committee has not yet reached a decision as to whether there is still sufficient interest in this subject to warrant continuation of the work. It is expected that a decision will be reached within a few weeks, at which time the original committee will be either reorganized or disbanded.

PUBLICATION OF STANDARDS

New Standards

During the past year the following new Standards approved by the SOCIETY were published:

- Inspection Handbook for Manual Metal Arc Welding (Emergency Standard, prepared by A.W.S. Army Ordnance Advisory Committee)
- Recommended Practices for Resistance Welding (Tentative Standard, prepared by A.W.S. Resistance Welding Committee)
- Recommended Practices for Automotive Flash-Butt Welding (Tentative Standard, prepared by A.W.S. Automotive Welding Committee)
- Specifications for Field Welding of Steel Water Pipe Joints (Tentative Standard, prepared by A.W.S.-A.W.W.A. Committee on Specifications for Field Welding of Steel Water Pipe Joints)

Revisions of Existing Standards

During the past year the following revisions of existing standards were published:

- Standard Code for Arc and Gas Welding in Building Construction (revision of 1941 Tentative Standard, prepared by A.W.S. Committee on Building Codes)
- Specifications for Iron and Steel Gas Welding Rods (Tentative Standard, revision of 1942 Tentative Standard prepared by A.W.S.-A.S.T.M. Committee on Filler Metal)
- Standard Welding Symbols (proposed standard to replace present "Welding Symbols and Instructions for Their Use," published in the July issue of The WELDING JOURNAL for the purpose of eliciting comments, criticisms and suggestions)

Standards to Be Issued Shortly

The following standards have been virtually completed and it is anticipated that they will be submitted to the SOCIETY for approval and publication in the immediate future:

- Specifications for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Electrodes (Tentative Standard, prepared by A.W.S.-A.S.-T. M. Committee on Filler Metal)
- Standard Specifications for Welded Highway and Railway Bridges (revision of 1941 Specification, prepared by Conference Committee on Welded Bridges)
- Standard Welding Symbols (revision of 1942 Standard, prepared by Committee on Symbols)

COOPERATION WITH GOVERNMENT AGENCIES

At the request of the Ordnance Department, the activities of the A.W.S. Army Ordnance Advisory Committee have been continued in the postwar period. During the war this Committee prepared the Ordnance Inspection Handbook for Manual Metal-Arc Welding and cooperated with the Ordnance Department on specifically assigned welding problems, including reviewing welding specifications prior to their issuance by the Ordnance Department. The value of this work to the Ordnance Department is indicated in the following excerpt from a letter received from Major General E. S. Hughes, Chief of Ordnance: "The splendid cooperative work of the Committee during the war and the demonstration of real interest in continuing in the postwar period are deeply appreciated by the Ordnance Department."

The A.W.S. Railroad Welding Committee has also been active during the past year in cooperating with the U. S. Army. At the request of the Transportation Corps that Committee submitted detailed comments pertaining to a proposed revision of Specification TCTS 43203—General Specifications for Welding Railroad Equipment for the Transportation Corps. These comments were received with much appreciation and the Transportation Corps has requested the A.W.S. Railroad Welding Committee to hold a joint meeting with representatives from the Transportation Corps for the purpose of completing a revision of this specification to the satisfaction of the Transportation Corps and industry.

During the past year several other government agencies have requested the SOCIETY for assistance in connection with various welding problems. Such requests have been received from the U. S. Office of Education, the Veterans Administration, the Department of Labor, the Smaller-War Plants Corporation, the Technical Advisory Service of the Department of Commerce, the Office of Small Business, and the U. S. Employment Service. In each instance the technical staff of SOCIETY Headquarters has cooperated to the fullest extent possible.

COOPERATION WITH OTHER SOCIETIES

During the past year A.W.S. representatives have continued to cooperate with the Technical Committees of other societies and organizations. The A.W.S. representatives on several subcommittees of the S.A.E. War Engineering Board have been withdrawn, due to the discontinuance of these activities that were intended to fill a temporary wartime need. The SOCIETY has also withdrawn its representation on the A.P.I. Committee on Field Welding of Casing, due to the termination of this activity.

CONCLUSION

The information contained in this report has necessarily been brief. Where further information on a particular activity is desired, reference may be made to the annual report of the individual committee concerned. These annual reports also describe the other work now in progress.

The Technical Activities Committee considers that the accomplishments of the technical committees in the past year reflect creditably upon the SOCIETY and upon the welding industry as a whole. The published standards, particularly, are evidence of the ability of the SOCIETY to render service to the technical needs of the nation's industry. In submitting this report, we wish to make grateful acknowledgment to those who are serving on the SOCIETY's technical committees, whose continued efforts have made these accomplishments possible.

REPORTS OF INDIVIDUAL TECHNICAL COMMITTEES

Automotive Welding Committee (C. D. Evans, Chairman)

During the past year the Committee has held three meetings. Its first standard, "Recommended Practices for Automotive Flash Butt Welding," has been approved and published. The following projects are presently under study by the Committee: Automatic Arc and Gas Welding Processes; Power Supply for Welding; Spot Weldability of Mild Steel; Repair Welding of Cast and Malleable Iron; Spot Welding Strength Standards; Spot Welding Tip Standards; Arc Welding and Surfacing Electrodes; Spot Welding of Coated

Steels; Welding Symbols; Resistance Welding Equipment Standards.

The Committee has correlated its activities with the activities of other technical committees of the SOCIETY through its representatives on these other technical committees.

At a recent meeting the Committee elected C. D. Evans, R. S. Phair and S. A. Greenberg, Chairman, Vice-Chairman and Secretary, respectively. A policy of holding a minimum of four meetings a year was also established at that time.

A.W.S.-Army Ordnance Advisory Committee (R. W. Clark, Chairman)

The A.W.S.-Army Ordnance Advisory Committee was appointed on Oct. 21, 1943, to assist on specially assigned welding projects as requested by the Army Ordnance Welding Committee.

The first task assigned to the Committee was the preparation of a manual setting forth that information which would assist the Ordnance Department inspector in more efficiently and expeditiously fulfilling his duties.

This assignment was completed and the Ordnance Department issued, under date of Aug. 1, 1944, ORD-M608-2, entitled "Ordnance Inspection Handbook for Manual Metal Arc Welding." This Handbook was re-edited and in 1945 it was published as an emergency standard of the A.W.S.

This Committee has undertaken the task of preparing similar handbooks on Resistance Welding, Brazing and Gas Welding. The material for these handbooks is in preparation either by a subcommittee or by the appropriate A.W.S. Process Committee, as is the case with Resistance Welding and Brazing.

This committee has also served as a medium through which the Ordnance Department has obtained comments from Industry on welding specifications.

The Ordnance Department has requested that this Committee continue in the same capacity as it did during the war. They feel that there is a definite need for an A.W.S. Technical committee which will act as a liaison between Ordnance and Industry on technical phases of welding.

Committee on Brazing (J. R. Wirt, Chairman)

This committee was organized Dec. 15, 1944, for the purpose of establishing standards and recommended practices for the application of brazing.

Three meetings of the general committee, one of the subcommittee chairmen and three meetings of subcommittees have been held during this year.

We have been working and still are working on the Inspection Handbook for Brazing. The outline of this handbook is almost completed.

Since the Brazing Committee is newly organized it was necessary to assist in revising the concept of brazing as a process which was being used by the Committee on Definitions and Chart and to secure their tentative approval of our idea that brazing is really not a welding process even though similar tools are used. To accomplish this purpose two of the members of the Brazing Committee sought and were granted admission to the Committee on Definitions and Chart.

Since the progress in obtaining brazing information has been much slower than the development in this field, the basic information has been obtained rather slowly.

We hope to complete the Inspection Handbook for Brazing early in 1947.

We expect to work on classification and standardization of brazing materials, standard methods of testing and standard recommended procedures during 1947.

We have two subcommittees functioning at present—one on High-Temperature Brazing; the other on Low-Temperature Brazing, which has a subcommittee on Light Metal Brazing.

Conference Committee on Welded Bridges (A. R. Wilson, Chairman)

The duties of this Committee have been the development of the Specifications for Design Construction and Repair of Welded Highway and Railway Bridges. The first specifications were issued in 1936, and subsequent revisions were issued in 1938 and 1941.

Subcommittees of the main Committee have been very active, both in meetings and by correspondence, in connection with a proposed revision of the Specifications. Such recommendations of the Subcommittees were compiled and submitted to the main Committee for consideration.

The main Committee has held two meetings during the past year, at which times the recommendations of the Subcommittees were considered, and we expect at an early date to submit a revised edition of the specifications, with our recommendation that it be adopted by the Society.

At the meeting of the Committee held July 17th the following officers were elected for the term beginning Oct. 1, 1946: Chairman, F. J. Pitcher; Vice-Chairman, Jonathan Jones; Secretary, S. A. Greenberg.

Committee on Building Codes (T. R. Higgins, Chairman)

This Committee, first organized in 1928 and reorganized in January 1940, has as its purpose the formulation of suitable building code regulations for the use of arc and gas welding in building construction.

The first report of this Committee entitled "Code for Fusion Welding and Gas Cutting in Building Construction, Part 'A'—Structural Steel" was superseded by the "Standard Code for Arc and Gas Welding in Building Construction," which was tentatively adopted by the SOCIETY in 1941.

The arrangement of the material and the manner in which the provisions were drafted were developed so that, either by citation or by embodiment in its entirety, the Standard Code could be adopted by municipalities and other governmental bodies in their building ordinances.

During the past year the Code, after a few relatively minor revisions had been recommended by the Committee, was adopted as a full standard.

No new work is contemplated by the Committee for the coming year.

Committee on Definitions and Chart (R. W. Clark, Chairman)

The present Committee on Definitions and Chart was appointed in 1938 and assigned the task of revising and bringing up to date the welding definitions prepared by an earlier Committee of the SOCIETY and issued in 1929 under the title "Welding and Cutting Nomenclature, Definitions and Symbols." The Committee completed its initial work in 1939, and its report was published in January 1940 under the title, "Tentative Definitions of Welding Terms and Master Chart of Welding Processes." During 1942 the Committee completed a revision of the tentative report, which was approved by the Board of Directors on May 7, 1942. In the process of this revision the report was advanced to the status of a full standard.

In 1944 the activities of the Committee were reorganized to insure that the requirements of all A.W.S. Technical Committees would be properly coordinated. The Committee membership now includes representatives of all Technical Committees of the A.W.S. and other interests concerned with nomenclature and definitions, such as the International Acetylene Assoc., Resistance Welder Manufacturers' Assn., A.S.M. Metals Handbook Committee, American Iron & Steel Institute Committee on Welding and National Electrical Manufacturers Assn. This Committee has looked to the A.W.S. process committees such as the Resistance Welding and Brazing Committees for recommendations which are prepared by their subcommittees, the chairmen of which in each case is a member of the A.W.S. Definitions Committee.

During the past year complete revisions have been made by all the working groups and one meeting has been held of the Main Committee to review the expanded chart of processes. It is expected that a complete revision will be available for approval in the early part of 1947.

A.S.A. Sectional Committee C-52 - Electric Welding Apparatus (E. M. Callender, Chairman)

This committee was organized under the sponsorship of the AMERICAN WELDING SOCIETY and approved by the American Standards Association on Feb. 28, 1941. The function of the committee is to revise the Standards for Electric Arc Welding Apparatus and Standards for Resistance Welding Apparatus originally issued in 1933.

Much of the work during the past year has been in the nature of organization and planning for the peacetime standards which the various subgroups are to prepare. One subgroup (Resistance Welding Machines) is now in the process of organization which is about completed, and it is hoped that they will meet in the near future to work out a program.

During the past year, the resignation of L. W. Clark as Chairman of A.S.A. Sectional Committee C-52 was accepted. It is with regret that the committee loses the able guidance of Mr. Clark, who has been closely associated with the work during its trying times. E. M. Callender was elected Chairman in his place.

During the summer convention of the American Institute of Electrical Engineers in Detroit, meetings of the various C-52 subgroups and the main C-52 Committee were held at the Rackham Memorial Building. Some of the reports rendered were encouraging, and it is axiomatic that

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A large group of editors and reporters from leading technical journals, newspapers, and newsmagazines recently attended a conference at NCG's Hollup Division factory for the preview of an important technological advance in the art of arc welding. Many of these men expressed surprise that they were allowed ready access to every part of the plant. They seemed especially surprised when they were shown all the details of the high-speed precision equipment that produces SUREWELD Electrodes. "Most manufacturers of electrodes," they said, "consider their methods vital commercial secrets."

There are two reasons why the methods of manufacturing SUREWELD Electrodes need not be treated as secrets. First, the equipment used has no counterpart in the industry. It was designed and built by NCG's Hollup Division engineers and is fully protected by patents. Second, no manufacturer without the huge volume which SUREWELD performance has built could possibly afford the investment in facilities comparable to those employed for SUREWELD production.

Visitors are welcome in the SUREWELD Electrode plant. To see the modern manufacturing methods which make SUREWELD precision and uniformity virtually automatic and inescapable . . . and to see the astounding volume which user preference for SUREWELD has made possible . . . these *facts* are far more convincing proofs of SUREWELD leadership than any comparison of competitive *claims*. For the satisfaction that *thousands* of users prove every day by their repeated purchases of SUREWELD Electrodes, you too should insist on the genuine and refuse all substitutes.

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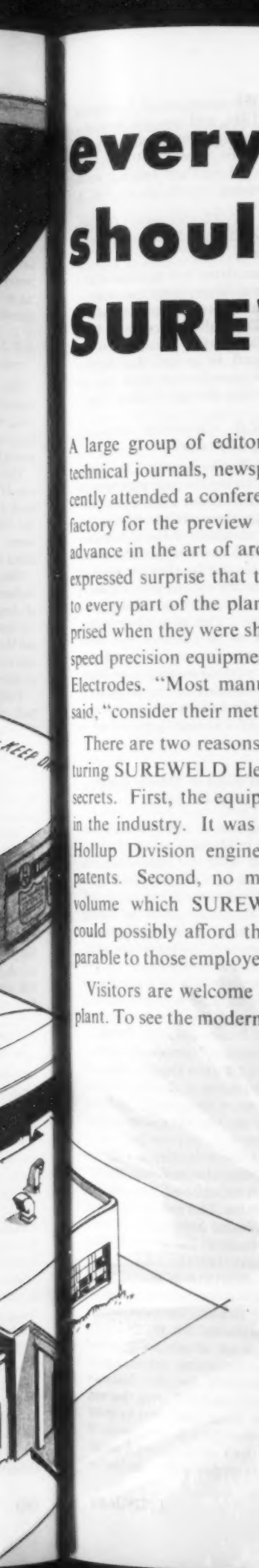

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the work should proceed toward a logical conclusion.

Attendance was good at all of the meetings and a high interest was manifested by members.

The following is a summary of the accomplishments during the past year of the various subcommittees and subgroups of this committee:

Subcommittee on Arc-Welding Apparatus (R. C. Freeman, Chairman)

This subcommittee has reviewed the 1945 edition of the N.E.M.A. Standard "Electric Arc Welding Machines and Electrodes" as a basis for an American Standard. This N.E.M.A. Standard had been submitted for review of the Subcommittee membership and modifications made based on comments received. Other American Standards such as the Standard on Electric Motors were also considered where applicable. A redraft of proposed American Standard on Arc Welding Machines is being prepared and will be submitted to members of the Subcommittee for approval. Following this approval, the standard will be published in THE WELDING JOURNAL for comments and then submitted to the Main Committee for final approval.

Subcommittee on Resistance Welding Apparatus (B. L. Wise, Chairman)

1. *Subgroup on Resistance Welding Machines (J. H. Cooper, Chairman).*—A list of proposed personnel of this subgroup has been formulated. Letters of invitation have been sent out, and when organization is completed, the subgroup will be asked to consider the R.W.M.A. Standard Specifications as a basis for preparation of an American Standard.

2. *Subgroup on Resistance Welding Controls (G. W. Garman, Chairman).*—This Subcommittee held a meeting and reviewed the N.E.M.A. Standard on Controls for Resistance Welding Machines together with the American War Standard on the same subject and applicable AMERICAN WELDING SOCIETY Standard Definitions. A program for preparation of a draft of an American Standard was formulated, and it is expected that a draft of the proposed specification will be available for consideration at a meeting of the subgroup in the Fall of 1946.

3. *Subgroup on Resistance Welding Electrodes (G. N. Sieger, Chairman.*—This subgroup held a meeting and decided to take no action in the preparation of an American Standard on Resistance Welding Electrodes for a period of six months in order to provide time for completion of investigations on this subject currently in progress.

A.W.S.-A.S.T.M. Committee on Filler Metal (J. H. Deppeler, Chairman)

The progress of the Committee during the past year is indicated by the subcommittee reports which follow:

Subcommittee I—Iron and Steel Arc-Welding Electrodes (J. H. Deppeler, Chairman)

This Subcommittee is engaged in a revision of the "Tentative Specifications for Iron and Steel Arc Welding Electrodes (serial designation A-233)." Four meetings have been held during the past year.

Subcommittee II—Iron and Steel Gas Welding Rods (J. H. Critchett, Chairman)

This Subcommittee has issued a 1946 edition of the Tentative Specifications for Iron and Steel Gas Welding Rods, representing minor revision to the edition published in 1942.

Subcommittee III—Aluminum and Aluminum Alloy Filler Metal (G. O. Hoglund, Chairman)

This Subcommittee has previously prepared the Tentative Specifications for Aluminum and Aluminum Alloy Metal-Arc Welding Electrodes. During the past year the Subcommittee has been engaged in the preparation of specifications for aluminum and aluminum-alloy gas welding rods. Several drafts of these Specifications have been prepared for study by the Subcommittee. Since no data were available to answer certain questions raised regarding some of the specification requirements, tests are being conducted to substantiate these requirements before considering the Specifications for final approval. These tests are practically completed and will be reported shortly.

Subcommittee IV—High-Alloy Steel Filler Metal (R. D. Thomas, Chairman)

This Subcommittee has completed preparation of Tentative Specifications for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Electrodes, which have been approved by the Main Committee and the Technical Activities Committee and are being submitted for final approval.

Subcommittee V—Nickel and Nickel-Alloy Filler Metal (O. B. J. Fraser, Chairman)

This Subcommittee has been inactive during the past year but it is hoped that the Subcommittee at a meeting to be held shortly may realize some progress.

Subcommittee VI—Copper and Copper-Alloy Filler Metal (C. E. Swift, Chairman)

This Subcommittee was organized in 1945 and has since been engaged in the preparation of specifications for copper and copper-alloy arc welding electrodes. Several drafts of the proposed specifications have been prepared and studied. A meeting of the Subcommittee is to be held in Atlantic City to consider a new draft based on previous comments of the members.

Subcommittee VII—Surfacing Materials (M. G. Sedam, Chairman)

This Subcommittee was organized in 1946 and held its first meeting in March 1946. A system of classifying surfacing materials was established at that meeting and data have been submitted by the members to be used in setting up chemical requirements for the classifications. As soon as this is done a meeting will be held to consider further specification requirements.

Subcommittee VIII—Capillary Brazing Materials

This Subcommittee was appointed by the Advisory Subcommittee at its meeting on Aug. 21, 1946, and the selection of a suitable chairman and membership is now under way. This subcommittee's work is to be limited to capillary brazing materials with melting points above 800° F.

Subcommittee X—Classification Designation of Filler Metal (R. David Thomas, Jr., Chairman)

This Subcommittee was appointed at a meeting of the Advisory Subcommittee on August 21st, and was assigned the following scope: "To establish a common basic system of classification designation for filler metal, and to assign classification numbers after consultation with the applicable committee through its Chairman."

A.W.S.-A.S.M.E. Conference Committee (C. W. Obert, Chairman)

The A.S.M.E. Conference Committee has continued during the past year to work with the A.S.M.E. Boiler Code Committee in coordinating the activities of the two groups. The members of the Conference Committee are all members of the Boiler Code Committee and by their presence on this Committee are able to give first-hand consideration to the various welding questions that arise. This plan of operation has continued to be effective and satisfactory as it permits matters of policy to be acted upon without hesitation or delay. As near as the Chairman can judge from the attitude of the Boiler Code Committee, there is no need for change in procedure or personnel.

Committee on Welding in Marine Construction (H. W. Pierce, Chairman)

Since its inception in 1929, the Committee on Welding in Marine Construction has concerned itself with the standardization of welding practices in the shipbuilding industry. The Committee has served to correlate welding requirements of the several maritime and naval code-writing bodies and to issue standards and reports on welding in shipbuilding as need arises.

In accordance with the first purpose of the Committee, its Subcommittee on Machinery Construction is presently reviewing the "Rules for Fusion Welding Piping in Marine Construction" prepared in 1944 and will attempt to modify the Rules to bring the requirements of the Navy Dept., American Bureau of Shipping, U. S. Coast Guard and U. S. Maritime Commission into full agreement.

As regards standards, the Committee has issued, in addition to the above "Rules," two reports on welding in hull construction titled: "Report on Thermal Stresses and Shrinkage in Welded Ship Construction" (1941) and "Structural Failures in Welded Ship Construction" (1944).

Tremendous expansion in quantity and size of ships during the war led to difficulties of varying nature, the most serious being the unexplained fracture of ships under conditions not usually accompanied by overstress. Extensive research projects were undertaken by the National Research Council, and following the war, certain ones are being continued by other government authority. As the reports of these investigations are removed from restricted lists, it is supposed that the Marine

Committee, through its Subcommittee on Hull Construction will screen and correlate the results into a Code of Recommended Practices.

This matter is to be discussed at the forthcoming meeting of the Committee to be held during the Annual Meeting of the Society at which time the personnel of the Committee will also be reviewed and revised as necessary.

Resistance Welding Committee (Wilson Scott, Chairman)

This Committee has concerned itself with the application of the resistance-welding processes to both ferrous and non-ferrous materials. During the past year the Committee has issued the "Recommended Practices for Resistance Welding" setting forth welding schedules based on good industrial practices covering spot, seam and projection welding of carbon and stainless steel and nickel, Monel and Inconel. These recommended practices also include data on flash welding and standard test methods for resistance welding.

Many of the subcommittees are engaged in further study of these recommended practices in order to extend the data to other thicknesses and different materials.

The Subcommittee on Spot Welding Coated Steels is presently engaged in the preparation of a recommended practice covering galvanized steels, and the Subcommittee on Definitions and Symbols has just completed a study of standard definitions and symbols to be incorporated in the A.W.S. standards on definitions and symbols.

Two new subcommittees, one on spot welding of aluminum and the other on spot welding of magnesium, are presently being organized. The Committee has also commenced preparation of an Inspection Handbook for Resistance Welding, which is to be similar in scope to the previously issued Inspection Handbook for Manual Metal Arc Welding.

A meeting of the Committee is to be held during the Annual Meeting of the Society to hold an election of officers and consider the future activities of the Committee.

Committee on Rules for Field Welding of Storage Tanks (H. O. Hill, Chairman)

This Committee was appointed by the Society on June 5, 1939, and assigned the task of developing general welding standards applicable to the construction of field welded storage tanks, operating generally at atmospheric pressure or at not over 15 psi. gage pressure.

A specification entitled "Rules for Field Welding of Steel Storage Tanks" was published under date of Dec. 12, 1940. During the year 1941 a few minor revisions were made for purposes of clarification. These were published as amendments and issued under date of May 7, 1942.

The following subcommittees of the main tank committee exist:

The A.P.I.-A.W.S. Conference Committee on Welded Oil Storage Tanks serves to advise the American Petroleum Institute Committee on Oil Storage Tanks regarding all matters relating to welding. The latest specification of the A.P.I. is No. 12-C entitled "All-Welded Oil Storage Tanks," dated August 1944.

The A.W.W.A.-A.W.S. Committee on Elevated Steel Water Tanks, Standpipes and Reservoirs prepared a specification for the American Water Works Association with the title "Elevated Steel Water Tanks, Standpipes and Reservoirs." The latest edition is No. 7H1 dated 1943.

The A.R.E.A.-A.W.S. Conference Committee on Welded Storage Tanks for Railway Service served in the preparation of a specification covering. "Welded Storage Tanks for Railway Service" which was issued in 1943.

The main committee and conference committees are standing committees which are prepared to review any matters presented to them by any of the coordinating bodies in regard to specifications for the field welding of storage tanks. The committee held no meetings during the past year. There were some items cleared by correspondence, particularly in the A.P.I. Conference Committee.

Railroad Welding Committee (L. E. Grant, Chairman)

This being the first report on the activities of this committee, it is considered desirable that the history of its formation be presented at this time, even though it covers a period longer than the past year. A preliminary meeting of the proposed membership of the committee was held in Chicago on April 27, 1945, with members of the American Welding Society Investigating Committee. At that time the need for such a committee and its probable field of usefulness was discussed. There was unanimous agreement on the need for such a committee. The American Welding Society Board of Directors formally approved the organization of the Railroad Welding Committee at its meeting on June 29, 1945. As a preliminary step in organizing the committee, a meeting of a number of the proposed personnel of the committee was held on Nov. 21, 1945, in Chicago, to outline the work of organizing the main committee at the meeting proposed for December. The committee was organized on December 14th in Chicago, at which time the officers were elected and the following scope adopted.

"The American Welding Society Railroad Welding Committee will be concerned with the formulation of safe, sound and progressive practices in the application of welding and associated processes to the railroad industry. The committee will bring together representatives of the railroads and car and locomotive builders for a mutual interchange of information; for the stimulation of new activities; and for the widest possible dissemination of existing welding knowledge."

It was voted to appoint three subcommittees as follows:

1. Subcommittee on Materials.
2. Subcommittee on Welding in the Fabrication of Locomotive Boilers.
3. Subcommittee on Welding in the Fabrication of Car Structures.

A meeting of Subcommittee 2 was held in New York City on March 29, 1946, at which time the outline of the subcommittee report was prepared.

A meeting of Subcommittee 3 on Welding in the Fabrication of Car Structures was held on June 17th in Chicago, at which time a number of topics were discussed with the object of selecting the most suitable ones for the first report. Work on this is now under way. No meeting of the subcommittee on materials has been held but the chairman of this subcommittee has been collecting information in preparation for a meeting of this subcommittee in the near future.

Because of the relatively new status of this committee it is not possible at the present time to indicate correctly the date when the reports can be expected to be completed. It is anticipated that a general meeting of the main committee can be held later this year at which time it is expected that at least preliminary drafts of the reports of the three committees can be presented to the full committee for discussion.

No new activities for 1947 are contemplated at the present time.

Committee on Safety Recommendations (H. S. Smith, Chairman)

Your Committee respectfully reports the following activities during the fiscal year 1946.

An inquiry with respect to whether or not the A.W.S. favor or discourage the use of plastic welding hood lenses of the various shades required in arc welding was referred to the Committee on Safety Recommendations. Your Committee suggested that the reply state that the American Welding Society has taken no position in the matter of whether such lenses are suitable. The inquirer was advised that the American Society of Safety Engineers, Engineering Section, National Safety Council, through its Research Committee has a research project in progress on the subject of plastic eye protectors and he was referred to that body for their comments.

In the report of this committee for the fiscal year 1945, it was reported that the American Standards Association had been requested to develop an American Standard on Safety in Electric and Gas Welding and Cutting Operations to supersede the War Standard Z49.1-1942 on the same subject. During the past year a committee to prepare this standard has been organized under the A.S.A. Sectional Committee procedure, with the American Welding Society acting as the sole sponsor body. Your Committee has cooperated with the staff of the American Welding Society and the American Standards Association informing this Sectional Committee, which work is about completed. Your Committee will continue to function in an advisory capacity to the American Welding Society and its representative on the Sectional Committee in connection with this peacetime A.S.A. standard development.

Committee on Standard Procedures of Welding and Standards for Welded Joints (C. H. Jennings, Chairman)

The Committee has been engaged in the preparation of welding procedures and joint details for arc and gas welding low-carbon and commercial low-alloy steels, for which purpose it was appointed on March 26, 1942.

To expedite progress in its assignment, the Committee has confined its considerations to date to preparation of an arc-welding procedure specification for materials in the "P-1, O-1" grouping of the Standard

Qualification Procedure, deferring work on a similar standard for gas welding. This Committee has not met since March 1944 and its activities have been forwarded through correspondence.

During the past year two additional revised drafts of the proposed procedure specifications were prepared and circulated for comments, the last one on July 30th. As soon as all comments have been received further plans will be made for forwarding the work of the Committee.

Committee on Standard Qualification Procedures (W. D. Halsey, Chairman)

This Committee was first organized in 1934 and reconstituted in 1937. Its efforts have resulted in the formulation of standards for the qualification of welding operators and welding procedures and the promulgation of these standards for adoption by code-writing bodies to effect a general uniformity of welding qualification requirements.

The most recent issue of these standard qualification procedures was published in 1941. More recently the Committee recognized the need for their editorial clarification and this task was undertaken in 1943.

In September 1944 a proposed revision of the procedure qualification requirements, together with explanatory appendices, were prepared and these were given preliminary consideration at a meeting on October 18th. More detailed consideration was given to the proposed revision at a later meeting on Dec. 4, 1944. Review of the comments received indicated some feeling on the part of the Committee that need existed for a major revision to the procedure qualification requirements. Accordingly the Committee was balloted on this question in November 1945 and by a slight majority it voted to proceed with the editorial revision already in progress.

A meeting was held on Dec. 5, 1945, and after several revisions had been suggested, "Standard for the Qualification of Joint Welding Procedures—Part I—Manual Arc Welding," representing an editorial revision of the present "Tentative Standard Qualification Procedure" was approved by letter ballot of the Committee in January 1946, with one member casting a negative vote.

In the meantime, some question arose regarding the advisability of issuing the editorial revision and it was decided to poll the Committee again on this question. A letter ballot was submitted to the Committee on July 8, 1946, asking them to indicate a preference for proceeding with publication of the editorial revision or setting aside the editorial revision and starting work on a major revision. All but one of the members returning a ballot indicated a preference for the second alternative. Two of the Committee members did not return their ballots.

Accordingly, plans are now being made for studying a major revision to the present procedure qualification requirements. In this connection it will probably be necessary to reorganize the Committee's personnel.

Committee on Standard Tests for Welds (M. F. Sayre, Chairman)

In July of 1945 the committee completed work on a standard method for conducting the tee bend test for weldability. This test was approved for inclusion in the SOCIETY's "Standard Methods for Mechanical Testing of Welds."

The most important development since that time has taken the form of correspondence and conferences dealing with the proper relative fields of work of the Committee on Nondestructive Tests for Welds, the Committee on Recommended Practices for Inspection of Welding and the Committee on Standard Tests for Welds. This study resulted in a decision to combine the two committees first named into a single committee having the title: Committee on Methods of Inspection. In line with this change, it was decided to limit the scope of the Committee on Standard Tests for Welds and to change its title to the Committee on Standard Mechanical Tests for Welds. This change was made in order to exclude from the committee's scope such nondestructive test methods as radiography and magnetic-particle inspection, which will now come under the new Committee on Methods of Inspection. In order to clarify this change in policy, the scope of the Committee on Standard Mechanical Tests for Welds was changed to read: "It is the function of this committee to develop standard methods of mechanical testing of welds, for adoption by code- and specification-writing bodies and for general use; to aid in coordinating standard test methods as proposed by other bodies."

During the past year this committee has also been active in preparing a draft of a standard test method for analyzing the chemical composition of metal arc-welding electrodes and gas-welding rods, as determined from the deposited metal. Although the proposed draft was virtually completed, the work was turned over to the A.W.S.-A.S.T.M. Committee on Filler Metal for further consideration, in view of the change in scope of this committee.

Committee on Symbols (L. C. Bibber, Chairman)

This Committee has been very active in the past year in preparing a revision of the SOCIETY's "Welding Symbols and Instructions for Their Use." As a result, a proposed revision entitled "Standard Welding Symbols" was published in the July issue of THE WELDING JOURNAL for the purpose of eliciting comments, criticisms and suggestions.

The proposed revision represents primarily a change in the method of presentation, intended to make the symbols system more readily understandable to the average user. The system itself has been retained as it was before, except for one or two minor changes in symbolization. It is anticipated that the proposed "Standard Welding Symbols," after slight modification to care for the comments and suggestions that have been received, will be submitted for approval and publication as a standard of the SOCIETY.

In preparing the new "Standard Welding Symbols," this committee has been assisted by several of the other A.W.S. technical committees, through their representatives on this committee.

A.W.S.-A.W.W.A. Committee on Specifications for Field Welding of Steel Water Pipe Joints (W. W. Hurlbut, Chairman)

This Committee was organized on Oct. 28, 1942. During the past year the Committee held a meeting and completed a tentative specifications entitled "Tentative Standard Specifications for Field Welding of Steel Water Pipe Joints." This specification was approved by both the AMERICAN WELDING SOCIETY and the American Water Works Association and was published under the A.W.S. Serial Designation D7.0-46T.

During the coming year comments on this specification will be considered with the idea of modifying the present tentative specification before it is advanced to the status of a full standard.

REPORTS OF A.W.S. REPRESENTATIVES ON TECHNICAL COMMITTEES OF OTHER SOCIETIES

American Standards Association

Sectional Committee A-10—Safety Code for Construction Work (A. N. Kugler)

This Committee was established by the American Standards Association for the purpose of drawing up the General Safety Code for the construction industry. This was accomplished several years ago and the final draft was published for the use of those interested. Welding is treated as a separate section in the Code and the use of welding in other phases of the construction industry are in all cases referred back to the Welding Section.

During the past year there has been no meeting of this Committee. One or two minor objections have been received but these do not relate to the Welding Section.

When the final draft of the Code was published it was decided to retain this Committee in a purely consultative capacity. This policy is being extended for the current year and it is therefore recommended that our membership be continued.

Sectional Committee B-31—Code for Pressure Piping (D. H. Corey and F. C. Fantz)

This Committee was organized several years ago to revise the first edition (1935) of the American Tentative Standard Code for Pressure Piping. The revision was completed and approved by A.S.A. in 1942, and the American Standard Code for Pressure Piping (A.S.A. B-31.1-1942) was subsequently published.

The Committee has held no meetings during the past year. However, inasmuch as the Committee will undoubtedly be concerned, at times, with matters of interest to the A.W.S. it is recommended that representation be maintained.

Sectional Committee C-42—Electrical Definitions (R. W. Clark)

This Committee approved a revised list of welding terms and their definitions in August 1941. Over 20,000 copies of this Standard have been sold since its publication in 1941.

This American Standard includes only welding terms which are electrical terms, and the balance of welding terms and their definitions will be found in the AMERICAN

WELDING SOCIETY's "Definitions of Welding Terms and Master Chart of Welding Processes."

This Committee, inactive during the war years, is now in the process of reorganization and will soon meet to consider the numerous suggestions for changes in the present terms of the Standard for Electrical Definitions, as well as new terms proposed for addition in the next printing of the Standard.

Sectional Committee Z-2—Protection of Heads, Eyes, etc., of Industrial Workers (H. S. Smith)

This Committee held one meeting during the past year which was devoted to consideration of a revision of the American Standards Safety Code for the Protection of Heads, Eyes and Respiratory Organs.

The principal activity on this subject of interest from the standpoint of the AMERICAN WELDING SOCIETY is the research study on plastic eye protection that is being conducted at the Battelle Memorial Institute under the auspices of the National Safety Council. In view of this research, it was voted to hold in abeyance the revision of that part of the safety code dealing with eye protection.

Sectional Committee Z-5—Ventilation Code (H. S. Smith)

There has been no activity on the part of this committee during the past year. While this committee has not yet considered anything that has directly to do with welding and cutting, it is quite possible that it will at some time in the future. For this reason I believe the A.W.S. representation on the committee should be continued.

Sectional Committee Z-10—Letter Symbols and Abbreviations for Science and Engineering (W. Spraragen)

The purpose and scope of this Committee is the standardization of letter symbols and signs for equations and formulas, and abbreviations for use in publications.

The Committee has produced during the past year the Standard for Letter Symbols for Chemical Engineering, Z10.12, and this is in process of being made a standard by the A.S.A. The Committee has also made progress on Physics' Symbols. Neither of these have any significance for the AMERICAN WELDING SOCIETY.

For some time I have questioned in my own mind the advisability of the A.W.S. continuing its representation in A.S.A. Sectional Committee Z-10. From my contacts during the past several years, I do not believe that any useful purpose is served by continuing any such representation. I would therefore recommend that the A.W.S. not continue its representation on A.S.A. Sectional Committee Z-10.

Sectional Committee Z-28—Work in Compressed Air (E. Vom Steeg)

There has been no activity in this committee during the past year.

Sectional Committee Z-32—Graphical Symbols and Abbreviations for Use on Drawings (L. C. Bibber)

Your representative on this committee reports that there has been considerable activity on the part of A.S.A. during the past year, resulting in the completion of a pamphlet on engineering abbreviations and other graphical symbols for use on drawings, other than welding symbols.

The A.W.S. welding symbols have undergone a revision during the past year with particular reference to the manner of presentation. As soon as the new presentation has been approved, the revised symbols will be submitted to A.S.A. for their consideration.

American Society for Metals

Metals Handbook Committee (H. L. Maxwell)

The work of the Handbook Committee of the American Society for Metals has been particularly active during the entire year in the preparation and revision of technical sections of the forthcoming new Metals Handbook. As the AMERICAN WELDING SOCIETY representative on the Handbook Committee, the writer attended called meetings and assisted in formulation of outlines and general plans for the new book. Your representative was appointed Chairman of a new subcommittee to organize a group of engineers and prepare a new section on "Causes of Service Failures in Metals" for the new Handbook. This assignment has been completed. Particular attention was given to the review of articles for the Handbook where they were concerned with any of the phases related to welding.

American Society for Testing Materials

Committee A-1—Steel—Subcommittee II, Structural Steel for Bridges, Buildings and Rolling Stock (C. E. Loos)

At the February 26th meeting, the Section on Structural Steel for Welding recommended that attempts to add carbon and manganese limits to A.S.T.M. Specification A 7-42 for the purpose of meeting the requirements of welding bridges and buildings in this specification be abandoned, and that an attempt to formulate a specification for a structural steel for welding bridges and building be made by the Section, with the thought that such a specification may replace or become Specification A7. This recommendation was unanimously approved by the subcommittee.

At the June 25th meeting a report was received from the Section on Structural Steel for Welding, following its meeting of the previous day at which a number of especially invited guests were present. At that meeting the discussion was directed to the field of safe use of A 7 steel for welded structures, in recognition of the great convenience and economy that result from the use of a steel of its strength, its availability and its base selling price.

The Section reported as follows:

1. That for the statically loaded parts of buildings A 7 steel is satisfactory up to $1^1/_2$ in. in thickness without special technique, and above that thickness can be kept so by proper technique.

2. That the same is true for most parts of highway bridges, assuming that a fair portion of dead load stress is included in the total stress.

3. That for railway bridges A 7 steel is satisfactory up to 1 in. in thickness, without special technique, and above that thickness is likely to be of a composition necessitating preheat and possibly other special techniques.

4. That there is a place for a specification for a steel for welded structures, the use of which should be considered when the thickness of a welded part is greater than $1^1/_2$ in. in the case of buildings and highway bridges, and 1 in. in the case of railway bridges.

5. That one characteristic of this new specification would be the placing of a limit on carbon and manganese, permitting the strength to taper off with increase of thickness.

6. That it remains for bridge engineers to determine, and that the Section cannot determine, whether any properties are essential in the steel which the present types of acceptance tests do not measure.

7. That therefore the writing of this new specification will encounter some delay.

8. That when such a new specification is adopted, the SOCIETY should clearly distinguish, for the benefit of the consumer, where A 7 may be used and where the new specification is advised. This may well be done in the respective scope clauses, although it is not recommended that the scope clause of Specification A 7 be thus modified at this time.

Committee A-10—Iron-Chromium, Iron-Chromium-Nickel and Related Alloys (L. M. Dalcher)

Your present representative was appointed on Dec. 10, 1945. There have subsequently been two meetings of this Committee, one of which was attended by your representative, and your representative has also been active through correspondence, execution of letter ballots, etc.

During the past year the only item of interest from the standpoint of the A.W.S. was the inclusion of repair welding provisions in two stainless steel casting specifications, one entitled "Proposed Tentative Specifications for Corrosion-Resistant Iron-Chromium and Iron-Chromium-Nickel Alloy Castings for General Application," the other entitled "Proposed Tentative Specifications for Heat-Resistant Iron-Chromium and Iron-Chromium-Nickel Alloy Castings for General Application." Your representative proposed certain modifications in the provisions relative to repair welding, which are presently being studied by the Committee.

Committee B-5—Copper and Copper Alloys (J. J. Vreeland)

The purpose of this Committee is to establish new specifications covering copper and copper alloys, as well as change the existing specifications to suit the requirements of commercial producers and users.

During the past year the Committee has made various changes in parts of specifications to satisfy both producers and users, but none of these changes had any bearing on the weldability of the metal or alloy in question.

It is my recommendation that the AMERICAN WELDING SOCIETY continue

maintaining a representative on this Committee, just for the purpose of making certain that no changes in alloy compositions will be made that will affect weldability. As yet, no such changes have occurred, but our representation on this Committee is quite important.

Association of American Railroads

Committee on Fusion-Welded Tank Car Tanks (J. J. Crowe)

As a representative of the AMERICAN WELDING SOCIETY, I have not been asked for any assistance by the A.A.R. Committee on Fusion-Welded Tank Car Tanks, but as a member of the C.G.M.A. Committee on Tank Car Tanks, I can report that welding is receiving favorable consideration on all new designs submitted for approval. It is recommended that the AMERICAN WELDING SOCIETY continue its representation.

Heating, Piping and Air Conditioning Contractors National Association

Editorial Committee (D. H. Corey)

This Committee was organized to revise the Association's Standard Manual on Pipe Welding. It is intended primarily for the use of piping contractors and architects. Meetings have been held at one- or two-month intervals during the past year. The revision is practically completed, and it is expected that the Manual will be published in 1947. It is recommended that the A.W.S. maintain representation until completion of the revision.

American Institute of Electrical Engineers

Committee on Electric Welding—Subcommittee on Power Supply for Welding Operations (W. F. Hess and G. S. Mikhalapov)

This Committee has not been called into activity during the past year. The Committee has remained inactive since its work of preparing a couple of bulletins was completed a few years ago. It appears to be one of those Committees which may remain inactive for a considerable period of time before some new development requires its further activity.

International Acetylene Association

Committee on Welding and Cutting Chapters of A.S.M. Metals Handbook (C. H. Jennings, R. W. Clark and H. L. Maxwell)

This Committee has been inactive for the last three or four years. This inactivity is apparently the result of the war conditions and the A.S.M. decision not to revise the Metals Handbook. (NOTE: Subsequent to the receipt of this report, this committee has again been called into action, and the A.W.S. representatives are actively engaged in the preparation of the welding and cutting chapters of the new Metals Handbook.)

Engineering Foundation—Welding Research Council

Progress Report for Period Oct. 1, 1945–Sept. 30, 1946

BY C. A. ADAMS, *Chairman*

The Welding Research Council is about ten years old. From very small beginnings (a contribution of $5000 from Engineering Foundation) the Council has grown steadily so that its annual budget is of the order of a quarter of a million dollars. It started as a peacetime organization with initial emphasis on a critical review of the literature, together with the formulation of programs of needed research. It has now caught up with the literature review, although that work will of course continue at a reduced rate. The Council has published some 70 critical digests of the literature on specific subjects, which constitutes the best reference library in this field. In its peacetime operations the Council gathered into its fold some 300 of the ablest men of this country, interested in welding research and related sciences. It developed research centers in some 30 laboratories, mostly in universities. It had to its credit many accomplishments and had made a good start in the formulation of vital welding research problems needing solution during the war. This foundation, including the literature reviews, well-equipped research centers and trained personnel, were widely used by the Government agencies and greatly accelerated their work, even when no credit was given to W.R.C. Of necessity, the Government projects were of a restricted, or a confidential nature. Nevertheless, in many instances close cooperation existed between committees and personnel of the Council and these Government-financed projects. With the cessation of hostilities, most of the Government restrictions were removed and many of the important results are now being cleared through the Council and made available to industry.

The reconversion period again found the Council in a sound position to serve, and looking ahead even farther it is beginning to set up its projects on a long-term basis, with time for the laying of that broad foundation which is so essential to the solution of these complex problems. The accelerated use of welding during the war has opened up new fields and opportunities It has also indicated many problems, or to state the case more accurately, it has brought about a realization of the necessity of digging deeper and securing a much more fundamental approach to the complex problems involved in the design, fabrication and use of all kinds of welded structures for the variety of services met in industry. It is interesting to take stock of some of the more important problems that have been solved, either completely or partially, and the problems remaining to be solved.

Some Accomplishments

Up to this time much attention has been given to the problems of residual welding stresses. This effort was necessitated by the prevalence of the cracking of ship plates and the actual loss of several welded ships through the extension of these cracks throughout the cross section of the structure. At about the same time failures occurred in other large field-erected structures, such as large gas storage tanks. It was found necessary to separate the so-called general or reaction residual stresses from those of a more localized nature. The importance and influence of design, workmanship and materials had to be evaluated. As a result we can now say that the so-called local residual stresses played only a minor part in these major failures, whereas the general or reaction stresses still must be given consideration, as they may advance or retard cracks once started, depending upon their direction.

In other words, residual stress may cause cracks as the weld metal cools to ambient temperature, but if such cracking does not occur during cooling, there is little danger from these local stress pockets. This has been pretty well demonstrated by thousands of laboratory tests as well as by a careful analysis of service failures. Moreover, it has been explained theoretically. It was on this account that we arbitrarily assigned this local residual stress problem to the field of weldability.

Since we may assume that design and workmanship will be more carefully controlled in the future, more attention is now being focused upon the increasingly important subject of materials. It has been found that there is a wide difference in the transition temperatures of steels made by the several methods now in vogue as evidenced by notched bar tests. However, these differences have not yet been quantitatively related to large welded structures. The Council and several other agencies will pay particular attention in the coming year to the study of why steels behave differently at low temperatures, and if welding seriously affects their behavior at these temperatures.

Again, different steels may show a wide variation in their susceptibility to strain aging, strain hardening and the like. It will also be necessary to relate these phenomena to the behavior of structures made from these steels and over the wide range of temperatures met in service.

A beginning has been made in understanding the benefits which accrue from preheating and post-heating treatments. As yet, this information is on a qualitative basis. Effort will be made to separate and evaluate the benefits which accrue from these treatments, in order that they may be properly controlled.

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The Council, through one of its committees, has obtained a mass of data giving the unit design stresses which may be safely used in butt, fillet, plug and slot welds used in structural members for bridges or other structures subjected to cyclic loads. Attention will be turned to discover the reasons for low values in fatigue under certain conditions and the possibility of bringing about improvement.

Outstanding accomplishments have been made in the weldability field. With certain very simple tests, it is possible to indicate the proper welding procedure to be used on a new steel in different thicknesses, different types of joints and different ambient temperatures, such as to prevent undesirable metallurgical structures in the steel next to the weld. Different types of electrodes and degrees of restraint have been evaluated. Fundamental cooling rate information has been obtained and tabulated. The effect of hydrogen in electrode coatings is being studied.

A great deal of work has been done in relating rate of strain, notch effects and temperatures for any given steel. This work, carried out with small specimens, will eventually be related to large structures.

During the year, the Council made arrangements for the preparation of a comprehensive review of our state of knowledge on the problem of fracture by an outstanding expert, Major John H. Hollomon. This review indicated the gaps of needed knowledge in the field of stress strain, plastic flow and fracture of metals. Although experts appreciate that much better structures could be made from steels susceptible to heat treatments, no proposals have as yet been formulated for making use of this information economically in everyday practice. The importance of workmanship has been brought out forcibly by these numerous studies.

Through careful scientific investigations carried out in one laboratory, it was found possible to spot weld hardenable steels, such as armor plate, without causing brittle structures next to the weld. This was brought about by carefully controlled timing of welding, including preheating, and postheating in the welding machine. It should be noted that these operations are automatically controlled and take place in a fraction of a second.

Structural engineers have been in the habit of designing for impact by arbitrary rule-of-thumb methods based upon practical experience and some test results. The Council, with its investigations of the behavior of welded beams under impact blows, has turned its attention to securing basic fundamental information as to the comparable effects of impact blows in causing stresses, deflection of beams and the like. This information will prove of great value to bridge engineers and others, regardless of whether or not the beams are fabricated by welding or riveting.

The quality of steel is also being studied in large heavy box girders each weighing some 15 tons at different temperatures and the prediction of the behavior of these huge beams through small specimens.

NEW PROJECTS

The Council is embarking on several investigations of considerable magnitude. Three of these are worthy of special mention.

Pressure Vessel Research

A large committee has been organized. The problem has been arbitrarily broken down into four main divisions—namely, materials, design, fabrication and testing and inspection. Each of these groups has formulated careful programs. Two of them are starting with comprehensive surveys of the literature. This work is closely coordinated with the more fundamental projects, particularly with that on the Mechanics of Welded Structures. The total budget is starting at $75,000 a year, already largely subscribed.

Resistance Welding Research

During the last year, the Council has endeavored to concentrate all of its resistance welding investigations under one committee. These operations heretofore were scattered among several groups including the Aircraft Committee, Light Alloys and the Resistance Welding Committee. Careful programs are now being prepared by the Resistance Welding Committee dealing with the fundamentals of spot welding, projection welding and flash welding. These fundamental investigations will be paralleled by comprehensive investigations of the fatigue properties of spot-welded joints. It is hoped that a $43,000 program can be financed in this field.

Mechanics of Welded Structures

The Government agencies as well as the Welding Research Council are beginning to realize that this problem is not a simple one. Problems arise through the rigidity and monolithic character of a welded structure which were either not recognized, or were relatively unimportant in riveted structures. The Council proposes during the coming year to organize on a nation-wide scale comprehensive and fundamental investigations which can be broadly classified under the title of "Mechanics of Welded Structures." The problems are so complex and so large as to require the ablest talent available and funds in larger quantities than can be normally expected in the operations of the Council. We hope to make up for this deficiency by cooperation with the Government agencies as described above.

PUBLICATIONS

The publications of the Council are recognized the world over. The size of its monthly Research Supplement increases year by year. In 1945 it occupied a volume of 672 pages. This will be exceeded in 1946 by about 20%. This monthly publication includes the published reports. However, in order to provide the contributors and research workers with current information of researches in progress, a quarterly mimeographed bulletin series was initiated and has received wide approval. Consideration is now being given to convert this quarterly series to a monthly series.

FOREIGN COOPERATION

The Council continues to cooperate with a similar body in Great Britain. It has contacts with other foreign welding research committees.